Meso-Level Co- Innovation Dynamic Roadmapping For Managing Systemic Innovations

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By

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Abstract

The proposed research aspires to provide new insight on issues of applied Roadmapping and advance the state of the art in Roadmapping and its practice. It provides a *conceptual model* and *an integrated process framework* for the development of a *Third Generation, Meso-level, Co-innovation Dynamic Roadmapping (from now on called 'Dynamic Roadmapping')*, which integrates policy, research, industry, and organisational roadmapping methodologies, in order to manage the development and adoption of systemic innovations in complex domains.

It has been developed to meet the needs of increasingly *complex systemic innovations* where multiple organisations are involved as *co-innovators* and many other intermediaries and decision makers need to be included in the innovation adoption process. These types of innovations are usually driven by the interplay of multi-dimensional and cross-impacting factors derived from changes in social, market, economic, political and technology systems. Thus, the 'Dynamic Roadmapping' does not presuppose a single desired future for complex domains, but several futures, based on the complementary strategic perspectives of inter-dependent stakeholders, which need to be contextualised and negotiated at various sectoral, national and regional levels in order to be adopted.

The 'Dynamic Roadmapping' approach supports the achievement of the realisation of the desired futures through two main components: a 'co-innovation group' and an 'observatory function'. The co-innovation group is formed from all the necessary co-innovators, adopters, decision makers and users that are needed in order for the innovations to be developed and adopted. Their function is predominately 'normative' describing "what they want to happen" and "how" it will happen. The observatory function provides foresight and sense making methodologies to the co-innovation group, in order to constantly review and adapt their roadmaps in light of the emerging changes that can impact the roadmaps' realisation and adoption.

A conceptual model and its theoretical grounding have been built in order to bridge support for roadmapping activities among different innovative communities (e.g. in policy, research, industry and practice) and foster their collaboration via stakeholders' innovation networks. The proposed conceptual model and its process framework have been evaluated in a case study in order to establish its validity in the European context and provide implications to theory and practice. A pilot of this framework is first implemented for the area of Technology Enhanced Learning (TEL).

The *impact* of this research is:

- Managing uncertainty in Future planning
- Managing and implementing emergent Roadmaps for systemic innovations
- Monitoring and adapt the produced Roadmaps according to change factors in emerging reality
- Ensure their adoption in complex domain

This research work has been funded by an EU Marie-Curry Fellowship grant via the DYRECT project no. 255182. The proposed integrated framework has been adopted by the EU TEL-Map project (in education sector) and EU CRe-AM project (in creative industry sector). It has been documented in many European project deliverables as well as in international conference papers, and in journal papers.

Publications Related to the work presented in this thesis.

Journal papers

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Nascimbeni, F., Aceto, S., Burgos D., Kamtsiou, V. 2015. *Supporting innovation in technology-enhanced learning: a stakeholder-based open approach, (in progress)*

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Special seminar workshop

Kamtsiou, V., Millwood, R. 2013. Learning Futures workshop, *Foresight Action Network'* London South Bank University, London. This workshop was held in 10th September 2013 after an invitation by the *'Foresight Action Network'* to host a workshop on the 'Dynamic Roadmapping methodology' with UK Foresight and Education experts. This event was funded by Shaping *Tomorrow* sponsors. The participants had a hands-on seminar of the 'Dynamic Roadmapping' methodology and model. The methodology was tried out using a hypothetical scenario aiming to education sector to support innovation with new technologies and advise policy, practice and industry.

Dedication

“To mom and dad”

Για την αγάπη τους, την συνεχή τους στήριξη
και την πίστη τους σε μένα.

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Chapter 1: The Rationale of 'Meso-Level' Dynamic Roadmapping for managing Systemic Innovations

Chapter 1 introduces the rationale for the third generation, 'meso-level', multi-stakeholder co-innovation 'Dynamic Roadmapping' as an integrated innovation management approach, which bridges *micro (or company-level)* technology roadmapping approaches with *macro (policy, research and sector level) technology foresight approaches*. It discusses why this approach is urgent and relevant today (main drivers for this research work), lists the underlining assumptions behind the concept of Dynamic Roadmapping and the research methodologies employed, the gaps and the research questions governing this work.

1.1 The overall purpose of the proposed research.

The ***overall goal*** of the 'Dynamic Roadmapping' model and framework is to support networks *of co-innovators* - as integrated stakeholder's networks - to coordinate their efforts in order to plan, develop and bring systemic innovations through to the point of adoption and mainstreaming, especially in a turbulent operating environment. The participating organisations identify common desired futures, derive, stress-test and monitor their own roadmaps for themselves to implement.

This is a holistic approach, which *integrates foresight, roadmapping and change management methodologies at a meso, multi-organizational, level.* It also combines *both top-down and bottom-up approaches for bringing the co-innovation networks together.*

'Macro' level foresight approaches are usually focused on the potential of emerging technologies and their assessment. They use exploratory approaches in order to inform future research, policy and industry agendas. Usually, these types of approaches have a long term perspective and they are driven by socio-technical and economic changes. They provide an impact analysis of PESTLE (whether **P**olitical, **E**conomic, **S**ocial, **T**echnological, **L**egal, **E**nvironmental) drivers and projected trends, which could affect an industry or a field in the longer term. But although, a good understanding of the possible technology paths and the associated PESTLE and market drivers is achieved, they often *lack the exploitation of these ideas at operational levels*. They often remain in the form of reference documents or guidelines, which are used as tools by policy bodies in order to: a) raise awareness and alert companies and industry groups on new opportunities in science, research and technology; b) alert researchers on potential applications of their technological innovations; c) bring networks of innovative communities together in order to achieve consensus on uses and impacts of emerging technologies (Porter et al. 2004). In other cases, they are included in the policy and research agendas of EU, national, regional and sectorial funding programmes. Hence, although succeeding in providing a basis for deriving new policies and directives, foresight approaches often may not be successful in achieving these challenges. This is due to lack of an innovation management process as an actionable framework for detailed planning, which is needed at operational levels, aspects usually found in 'micro' (company) level roadmapping methodologies.

'Micro' level or company roadmapping, although a very good approach at integrating market drivers and technology planning at business levels of an organisation, it pays very little focus on changes driven by PESTLE contexts. Therefore, it is not effective to deal with future uncertainties and surprises. Roadmaps are regarded as normative approaches, which focus on a top-down vision (desired future) and the identification and mapping of milestones, resources and operational plans to achieve it. In that respect, unlike foresight approaches, which are mostly informational in nature, roadmaps are plans close to market, which focus on implementation through action. The challenge with micro-level roadmaps is that since they are focused mostly on new opportunities driven by technology and business drivers, they are looking at the future as one straight line scenario from the present to the future. Therefore, they are only suitable for dealing with incremental innovations where progress can be forecasted and managed. Thus, they are characterised as linear and isolated technology forecasts, which are not fitted for planning for systemic and complex innovations (Pagani 2009), (Rader & Porter 2006), (Beeton et al. 2008).

An integration of foresight (macro) and roadmapping (micro) approaches at process levels is therefore necessary. Such integration will link the operational innovation activities *(micro-level)* to both, a) the societal, technological, and economic drivers *(macro-level)*, and b) the shared strategic and business perspectives of the actors involved in the innovation chains *(meso-level)*. Thus, it integrates foresight (policy roadmaps), research and technology (research and industry roadmaps) methodologies with the strategic planning of stakeholders at their operational and innovation management plans (practice, co-innovation roadmaps). Moreover, macro-level foresight methodologies will support innovative communities to keep their roadmaps agile through the continuous monitoring of factors, which could have an impact on the roadmaps' implementation and adoption.

In addition, both macro and micro level roadmapping methodologies are usually top-down driven (Cho 2013). Macro-level roadmaps are usually based on experts' opinions and are driven by the policy agendas of government agencies or other type of policy organisations, while micro-level roadmaps are driven by an organisation's (e.g. a company) goals and strategies set by the organisation's top management. Thus, they often lack the wide consensus of all actors involved, which is needed for the roadmaps implementation and adoption. 'Dynamic Roadmapping' applies Bottom-up methodologies, based on conceptual modelling and disagreement management approaches, in order to bring likeminded stakeholders together for developing and implementing their roadmaps. For this purpose, a domain cartography is used to map, capture, externalize, aggregate and contrast the views of different innovative communities and their respective stakeholders, in order to provide a landscape for the domain in terms of: where capacity is building; what are the dominant believes and assumptions; who is doing what; using what technologies; what is perceived as threat or/and opportunity; and what are their main visions and future plans. Based on this cartography, the innovative communities with shared and/or complemented views are brought together to form the roadmapping co-innovation groups (innovation value networks) that will develop the dynamic roadmaps. Therefore, collaboration is driven by the innovation communities shared issues, objectives, activities and is based on common needs. This provides an internal motivation for the communities to collaborate towards commonly agreed desired futures, stemming from shared motives and objectives and not by forced or artificial consensus. Bottom-up approaches are well suited for solving the problem of creating superficial utopias as desired futures, but they have an inclusivity problem. Therefore, the domain cartography and weak signals analysis are used in order to make sure that: a) all the necessary roles and resources to develop and implement the roadmaps are included in the co-innovation group and b) the co-innovation group takes into account aspects about the future (at both micro and macro levels) that might otherwise be dismissed as possible because they might not be considered attractive. Or they might have to be overlooked, since they are not regularly associated with the particular activities of the group ((Kamtsiou & Klobučar 2013), (Kamtsiou 2014).

Finally, *adoption and change management models* are applied in order to ensure that all actors involved in the roadmaps' innovation chains will be brought together and agree to implement the planned actions. This is particularly appropriate for systemic innovations, where multiple organisations are co-innovating, and other value chain participants need to make coherent changes in order for an innovation to be adopted. In addition, it is also argued that this approach can be also adopted wherever a government or charitable foundation funds pre-market R&D and wants to see greater resulting impact, but, by working evenly with players across the sector, without interfering in the marketplace.

The *theoretical frameworks* grounding this research work are the SECI framework of knowledge creation, the Historical Cultural Activity Theory, cartographies of controversy, systems thinking, and adoption management models. Accordingly, different disciplines are involved in this research from the fields of knowledge and innovation management, including sense making, conceptual modelling, strategic planning and roadmapping, change management and adoption models and foresight analysis methodologies such as scenario planning, Future Search Conference (FSC) and weak signals analysis.

This research work used Action Research methodologies in order to develop new concepts, models and step by step processes for managing systemic innovations. The new concepts, models and frameworks comprising the 'Dynamic Roadmapping' approach were validated via practical implementation in the field of Technology Enhanced Learning in schools sector. The case study has focus on the creative classroom societal challenge: 'changing schools to creative learning environments. A co-innovation group of more than 134 European stakeholders was formed with the main purpose of driving towards a better TEL future in European schools.

In summary, the work in this thesis addresses a major gap in the area of innovation management of systemic innovations which need to be adopted and scale in volatile environments characterised by turbulence and change. This is a new and critical task, which requires bringing together many players at a meso-level, as co-innovation groups of stakeholders, who would have to come to an agreement on their desired future, what they have to do to achieve it and then oversee its realisation. A continuous adaption and monitoring of the roadmap's context is also required in order for it to enable successful long-term adoption. Addressing this emerging multi-player, meso-level innovation is the main contribution of the 3rd generation roadmapping approach illustrated here. The introduction of a method of establishing the co-innovation group and their shared desired future is also new. These important contributions of the new 'meso-level' approach in innovation management theory and practice are further analysed and discussed first in chapter 3 which underpins the theories behind the 'Dynamic Roadmapping' model and underline the processes for developing it; in chapter 7 which discuss the findings from the applicable implementation of the model (case study chapter 6) and the challenges faced; and in chapter 8 which summarises the conclusions and suggest further research in the area.

1.2 Relevance of Dynamic Roadmapping today: Main Drivers.

This research work is based on the real and urgent needs to assist people to deal with the problems associated with Meso Level types of roadmaps and the development, management and adoption of systemic innovations. The Dynamic Roadmapping approach for systemic innovation management is derived by the following drivers:

A. **The increased need for new innovation management approaches to cope with turbulent and volatile times**

The past few years, we have been facing economic recession, deep cuts in education, increasing unemployment and disbelief in the effectiveness of the European policies. In times of high uncertainty, and economic downturn, the focus is typically shifted to short-term operations planning, rather than long-term strategic planning and investments. Forecasting any developments or trends that span longer than two to three year is becoming very difficult if not impossible. Thus, both technology and policy foresight tend to be very short sighted. The emphasis is on the current demands, quick wins, deep cuts in R&D funding in favour to application oriented funding, rather than, focus on the development of basic and challenging technologies and strategic long term visions. Similarly, innovations tend to be close to market, driven by fast changes in market requirements and shorter products' lifecycles, market turbulence and rapid technological developments (Könnölä 2007), (Smits & Kuhlmann 2004), (Smits 2002). This type of short-term planning has negative effects in long-term sustainable development and competitiveness for both organisations and industries. In a similar economic situation in Japan during the 1990s, the so-called "lost decade" of Japan's economy, many large private companies drastically reduced their R&D expenditures in order to cut costs. This strategy resulted in a short-term business upturn, but later proved to have contributed to a long-term competitiveness downturn. At the same time, there was a change in Japan's governmental technology policy towards prioritizing 'application-oriented' industrial technology, which resulted in short-sighted R&D support. However, the lesson from the situation in Japan in the 90s has revealed that in the longer term, the companies that had invested their resources into 'challenging' technology, or sometimes 'basic' research, when this was combined with a clear future visionary framework, they became more competitive and innovative; examples include Toyota, Canon, Toray, Sharp and Nihon Zeon

(Yasunaga et al. 2009). It is argued here that this phenomenon seems to be clear evidence to show that long-term R&D is an engine for sustainable growth.

In addition, the many uncertainties which characterise volatile environments and economic crisis can often cause a shift from “market driven” to “technology driven” applications, which are *lacking explicit assumptions concerning future needs or societal changes*. This may shift the focus from the needs of the customers to technology driven possibilities only. Therefore, planning is focused on technology pushed applications, which are within the radar and capabilities of the current technical community, often limited to recycling existing ideas (Strauss & Radnor 2004). This is especially true for sectors like education for example, where relative new concepts (such as MOOCs based universities, personalised learning, informal learning based diplomas, etc.) are still fuzzy, driven by many research options, and which lack shared perspectives. They are characterised by fragmented and sometimes conflicting technology driven solutions/visions, which are often met with strong dependences and/or resistance coming from existing pedagogical and business practices.

A governmental policy becomes very important in order to support ‘challenging’ or ‘future-business oriented’ R&D activities, which are accompanied with promising and persuasive scenarios for future commercialization, and which at the same time are addressing important societal needs.

In times of high uncertainty, the focus of Roadmapping as innovation management and strategic planning needs to be shifted:

- From short term planning to operational plans which are driven by a widely shared long term strategic visionary framework, and research agendas.

- From expert-based to value networks stakeholders-based; This shift will provide a stronger implementation focus, where stakeholders themselves will develop a consistent view of the domain, including concepts such as desired futures, opportunities, threats and gaps, and they will ensure that these futures are implemented and managed.

- From technology push to a better understanding of explicit and implicit assumptions concerning future needs and the respective drivers stemming from societal, political, environmental, economic changes and technological innovations.

- From *Static* to *Dynamic* Roadmaps: The desired shared understanding (common visionary framework) and the operational plans for achieving this shared future, must be continually monitored, testing and renewed in order to take into account new technological opportunities, socio-economic changes and to provide a solid foundation for decisions. This is particularly true, under dynamic and volatile conditions.

B. Very fast technological changes

Vast technological changes such as in nanotechnology, biotechnology, information and communication technologies, semiconductors, and materials are envisioned to create major structural changes in economy and society. Moreover, the experts see technology convergence in for Nanotechnology, Biotechnology, Information technology and Cognitive science, as well as in domains such as Information Technologies, Telecommunication, Consumer Electronics, and Entertainment Innovations and Multimedia (Tierney et al. 2013), (Bainbridge 2009), (Porter et al. 2004). Innovations today are more likely to happen on the interface of more than one technology or from technologies that converge from different scientific disciplines and fields. Therefore, it is becoming more and more complex and difficult to make any sound technology predictions and assessment about their evolution and use. At the same time Internet evolution, including social media provide individuals freedom of expression, opportunities to develop global ventures and demand for more equality in social settings.

C. The increasing need to introduce and manage complex systemic innovations

Increasingly more innovations today are not linear or incremental, but systemic and complex, which are depending on and driven by complex interactions between many actors, groups, organisations, and their operating and contextual systems (Kaivo-oja 2011). The increasingly systemic nature of innovations in complex domains such as in education, energy, pharmaceutical and healthcare sectors, require the development of new integrated innovation management models that account for the constantly changing requirements in society, the fast technological changes, the global competition and the complexity of adoptions of such innovations. Developing roadmaps based on extrapolated technology forecasts beyond short terms is very difficult for complex adaptive systems and domains, which are characterised by systemic linkages among various types of stakeholders and decision makers, heavily policy regulations, social sensitivity in new offerings, fast technological changes, and different socio-economic contexts, and increasingly shorter product life-cycles.

There are key challenges involved when dealing with systemic innovations.

- The difficulty related to sense making of complex systems, the many uncertain factors and drivers affecting these systems, and the dynamics of the system changes. The system is not independent from its context. The system and the environment are continuously both influence and dynamically transforming each other.

- The need for new innovation management approaches which need to prepare organisations for alternative, even radical or disruptive futures and the respective uncertainties and possible discontinuities in the future development.

- The discontinuous and or disruptive nature of these innovations to current institutional and governance structures creates huge difficulties for their adoption and scale. They often require significant re-structuring to ensure effective implementation and diffusion. Therefore, systemic innovations have potentially significant structural and large scale impacts to society and organisations.

- Even when a good understanding of technology paths and PESTLE uncertainties is achieved, the active formulation of new ideas and their subsequent exploitation at operational levels is very difficult to achieve.
- The difficulty to gain consensus on a desired future among the many diverse types of stakeholders who are having different agendas, motives, approaches, and starting points.
- The difficulty to develop none linear trajectories for a combination of emerging technologies. These are convergent technologies that need to be developed in different pathways, shaped by many drivers and applied in different contexts.
- The difficulty to make sense and analyse not only the innovation process, but also the significance of interconnection among the actors in the innovation process, and the also understand and assess the impacts of other formal and informal networks and processes which can be in favour or in conflict with other systems.
- Due to the complex nature of systemic innovations their adoption and scale up of systemic innovations take over longer time. It is difficult to manage the adoption and scale of such innovations and make sure that both their goals/solutions and their operational plans are relevant over time. This makes the actual implementation of the roadmap and its adoption a key challenge.

1.3 Assumptions in Dynamic Roadmapping

The Dynamic Roadmapping as an approach for Systemic Innovation Management is defined as:

1. Technology Roadmapping (TRM): the strategic, innovation and operational plans that need to be developed, mapped out and coordinated over time by a co-innovation group of stakeholders, in order to achieve a common visionary framework (desired future), taking into account opportunities and threats stemming from technological developments, and from anticipated changes in the wider PESTLE contexts.
2. ‘Dynamic Roadmapping: the process of continuously monitoring the PESTLE contexts using foresight activities and sense making in order to support the co-innovation group to timely review and assess the effectiveness and efficiency of their desired futures and roadmaps and adapt them in order to fit the new circumstances.

Unpacking these, the Dynamic Roadmapping approach makes the following assumptions:

- Innovation is not a linear process starting from a discovery in a lab to commercialisation, but rather a participatory learning process.

- There is a shift in perspective from positive technology push approaches to the potential of technologies to support socio-economic trends, social needs and business needs.
- Roadmap aims to support foresight and strategic planning activities across multiple stakeholders. Roadmaps are used as a methodology to express commonly agreed destinations or desired futures as a common visionary framework for short, mid and long term time horizons.
- Not all stakeholders will agree on a single desired future, so we expect multiple desired futures that might be complimentary or in conflict. In order for the roadmaps to have a real chance for implementation stakeholders with complementary plans and visions need to come together.
- Disagreement management approaches need to be employed, in order to map out these desired futures, balance any power structures, as well as link them to the actors in the domain (likeminded stakeholders), their motives, activities, plans and communities.
- Any Roadmap itself makes a number of assumptions about the future operating contexts.
- Such assumptions about the future are carrying varying degrees of uncertainty.
- Foresight is used to deal with critical assumptions that have high uncertainty with various degrees of impact.
- Uncertainty generates multiple possible, but equally plausible, futures.
- Each desired future should be played out (stress-tested) in each of the plausible contexts.
- For the Roadmapping framework to be dynamic, a monitoring function is needed to determine which plausible future is actually emerging.
- Such monitoring can be used to select the roadmap branch that is appropriate to the emerging context.
- Near term future uncertainty is much less than long term future uncertainty.
- The near term section of a Roadmap can be used to guide current stakeholder activities, such as their short term operational plans and support them in their innovation management planning in midterm, and strategy development in the long term.
- Continuous monitoring of relevant trends and events is needed in order to review and adapt the Roadmaps, the assumptions about Future Contexts and the feasibility of

Desired Futures. Therefore, adapt the Roadmapping visions and roadmapping processes according to this analysis of the emerging reality.

- As the time progress, the mid-term plans are updated via this monitoring function and become short term, and the long-term strategies are evaluated as to the pertinent relevance of their strategic goals.
- Coordination for the roadmaps adoption needs to be done at the systemic levels all co-innovators, intermediaries and adopters, who are involved in the roadmaps' innovation chains.

1.4 Gaps in existing roadmapping practices related to Meso Level roadmaps

Main gaps related to meso-level roadmapping include:

- The lack of integration among Technology Future Analysis (FTA) approaches such as Foresight, Technology assessment and Roadmapping in order to effectively plan systemic innovations and coordinate and monitor their adoption.
- The lack of a holistic approach that would integrate and optimise industry, policy, research and practice via 'meso-level' roadmapping approaches at process levels. This integration is needed in order to a) align the contributions of all different actors involved in the roadmaps' innovations value chains; b) provide PESTLE drivers and context-sensitivity analysis of the roadmaps in order to support their adoption and scale-up, in a range of plausible futures; c) provide an approach that enables innovation funders to reduce the risks and maximise the benefits of their funded programmes and projects with a chance to adoption and scaling up; d) provide long term support for R&D development which is tied to commercially viable and socially desirable goals.
- The lack of an integrated observatory function, which will support the dynamic adoption of the roadmap in a turbulent world. This is a core function, which will set out the main stages and processes for meso-level type of roadmapping. Since, it would be impossible to find our way to a new place with an old map, the observatory function deployed a new type of domain 'cartography', which is extensible, diverse, continuously updated and integrated into the roadmapping process. This includes describing where the visions converge and where they diverse, where the tensions are, what is the role of ICT and what are the barriers and obstacles that needed to be lifted.
- The lack of a step by step approach for meso-level roadmapping at process levels, which can then be implemented by others, who wish to develop and manage systemic innovations. This includes systematic methodologies for forming roadmapping co-innovation groups, developing foresight, technology assessment and roadmapping processes and coordinating the roadmaps' adoption.
- The lack of a theoretical grounding for meso-level Roadmapping processes.

1.5 Research questions

This research work was motivated by the observation that many successful EU R&D funded projects lack any significant take-up. This observation is based on *two main hypotheses:*

1. The first was that changes produced by these types of innovations are of systemic nature and successful adoption requires coordinated agreement, on both the provider and adopter sides, by multiple players involved in the innovation system.
2. The second was that implementation of systemic innovation takes place over a relatively long time and that unless changes in the transactional and contextual environments are taken into account, they can derail the effort.

These give rise to *two core research questions* which are broken down into further more focused research questions:

1. How should a complex, systemic innovation, which can have multiple stakeholders on both the provider and adopter sides, can be managed and coordinated?

   This was broken down into:

   - How can the future planning of multiple key stakeholders be integrated into a shared desired future, such that it can inform collaborative roadmapping activites related to planning, co-ordination and implementation?
   - How is it possible to ensure that the desired future, and consequent goals and roadmaps, fit with values and goals of the players involved?
   - How to create and maintain a domain cartography in order to provide the needed interoperability checks between the roadmaps developed by different groups, using different approaches, starting points, interests and motives, so that to increase their chances for a common understanding, adoption and sustainability?

2. What processes are needed for creating and adapting the roadmaps, given a relatively long, 8 to 10 years implementation horizon, in order to take into account future changes that might impact them?

   This was broken down into:

   - How can an appropriate actionable roadmap be developed to drive the operational implementation of the systemic innovations over a sustained period of time?
   - How can the roadmapping process remain agile in the face of continuing changes in the roadmaps' wider transactional and contextual environments?

1.6 Research methods used for the development of the integrated Dynamic Roadmapping Framework and Conceptual model.

Table 1 classifies the research methods used in this thesis in four main areas.

Chapter	***Research Part***	***Methods***
Chapter 1 *Chapter 2* *Chapter 5*	Gaps, Research Questions and Assumptions. A rigorous literature review was conducted in order to identify the research gaps and research questions related to the framework. This was backed up by a field work review of prior Roadmapping practice in TEL domain.	- Literature review - Field work review - NVIVO tool for categorization - Conceptual modeling of the results
Chapter 3 *Chapter 5*	Research framework: Meso-level Co-innovation Dynamic Roadmapping Theoretical grounding of the Meso-level Co-innovation Dynamic Roadmapping Framework Secondary data were also used from prior field work as contributions to dynamic framework from practice.	- Literature review theories and methods - Prior Field work review - Conceptual modelling - Generation of models and structures for developing the conceptual model of 'Dynamic Roadmapping' model - Generation of models and structures for developing a process framework - Overview of relevant research Methodologies - Theories used for developing the 'Dynamic Roadmapping' Framework: o SECI-Framework of Knowledge Creation o Activity Theory o Foresight o Roadmapping o Systems Thinking
Chapter 4	Research design Philosophical Underpinning of the chosen research methods and theories	- Field work, Systems Thinking, Action Research, FSC, Case Study
Chapter 6 *Chapter 7* *Chapter 8*	Practical implementation of the Meso-level Co-innovation Dynamic Roadmapping Model, Co-innovation group formation	- Action Research – field work - Case study - Participants observations - Workshop organisation, Workshop facilitation - Learning cafes, adapted Search event, scenarios, stress-testing, trends analysis, bottom-up conceptual cartography, weak signals analysis, surveys, bibliometric, Social networking analysis, conceptual modelling, change management. - Documentation and records - Conclusions

Table 1: Research methods applied in this research work

The first area describes the Gaps as they have been identified from the literature review and field work; the Research Questions and the research objectives, derived from the gaps and literature review; and the assumptions made in relation to the Dynamic Roadmapping concept. A broad literature review was carried out in roadmapping, foresight and innovation management approaches. This was accompanied by an analysis of the author's previous field work in managing and implementing roadmapping and foresight methodologies, within European roadmaps in the area of Technology Enhanced Learning (TEL).

The second area provides a) a theoretical grounding for the Dynamic Roadmapping framework. Literature review in the related theories was carried out. This area also describes which theories or which aspects of each theory were applied in the 'Dynamic Roadmapping' framework and how. Theories that were investigated were learning theories, such as the SECI theory for Knowledge Creation, Activity theory and Systems thinking. A connection of these theories to the Dynamic Roadmapping model and its methodologies was made.

And b) describes the conceptual model and process framework of the Dynamic Roadmapping. A literature review was continued in approaches that integrated roadmapping, foresight and innovation management methodologies. Different approaches were compared and analysed. The results were combined with the author's own field work in roadmapping projects. Conceptual modelling was used in order to develop the Dynamic Roadmapping framework.

The third area relates to the Methodology and Research Design applied for this work. It analyses the rational for the chosen research methods and the challenges faced in the context of this PhD work.

The fourth area presents a case study, which was carried out involving a diverse range of stakeholders from the academia, industry, policy and technology experts in Technology Enhanced Learning (TEL). This Case Study approach was used in order to empirically ground the theoretical model for Dynamic Roadmapping, through its practical implementation. It is used as pilot or feasibility method, which demonstrates how the Dynamic Roadmapping theoretical framework was successfully and practically implemented by a community in a real-life context. It was a very big practical element based on Action Research which span over 3 years. The case study was developed within the EU TEL-Map project and was focused in the school's sector.

1.6 Thesis structure

The thesis is organized in 8 chapters including this chapter (chapter 1).

Chapter 1 provides the main concepts and purpose of this research and its relevance today. It analyses the main drivers and assumptions behind the 'Dynamic Roadmapping' approach and discusses the challenges and research questions. Based on this analysis the key research questions of the 'Dynamic Roadmapping' approach are identified.

Chapter 2 discusses the findings of a literature review performed in order to: a) provide an understanding of the various concepts and methodologies involved in the 'Dynamic Roadmapping' model for systemic innovations; b) analyse gaps in the literature; c) and reflect on how these gaps were addressed by the 'Dynamic Roadmapping' conceptual model and process Framework.

Chapter 3 It presents the conceptual model of the integrated 'Dynamic Roadmapping' approach and its main principles. This is achieved by discussing the theoretical grounding of the 'Dynamic Roadmapping' conceptual model with the aim to provide connection between the model's methodology and the theory that grounds this research work. Then, it presents the actual stages and process involved in the 'Dynamic Roadmapping' framework.

Chapter 4 discusses and classifies the research methods used for the development of the integrated Dynamic roadmapping conceptual model and framework.

Chapter 5 presents the results of a secondary data analysis related to prior field work of the researcher in Roadmapping and Foresight approaches in EU TEL projects. It demonstrates how this practical research has contributed to both identification of gaps and to the development of the Dynamic Roadmapping Model.

Chapter 6 provides a case study in order to synthesise and analyse the results from the Action Research and demonstrate how the 'Dynamic Roadmapping' framework was implemented in School education sector. This case study is based on the implementation of the framework by the TEL-Map project (European coordination and support action).

Chapter 7 Further discuss the contribution of this research work in theory of innovation management and how this ties to the results of the case study.

Chapter 8 discusses the main impact of this research work in developing and managing systemic innovations with emphasis on the limitations of the case study and recommendations for future academic research.

These important contributions of the new 'meso-level' approach in innovation management theory and practice are further analysed and discussed first in chapter 3, which underpins the theories behind the 'Dynamic Roadmapping' model and underlines the processes for developing it; in chapter 7 which discusses the findings of this work and challenges faced in relation to the results from the case study; and in chapter 8 which summarises the conclusions and suggest further research in the area.

Chapter 2: Literature Review

This chapter summarises the findings of a literature review performed in order to a) provide an understanding of the various concepts and methodologies involved in the 'Dynamic Roadmapping' model for systemic innovations; b) identify gaps in the literature; c) and show how these gaps are addressed by the 'Dynamic Roadmapping' conceptual model and process Framework. Whenever possible, a link to Technology Enhanced Learning (TEL) is provided as an illustration or example, since TEL serves as an application domain for the ''Dynamic Roadmapping' model.

This chapter provides an overview of foresight, innovation theory and roadmapping methodologies from an evolutionary perspective, in order to identify gaps and set the stage for the Meso-level 'Dynamic Roadmapping' conceptual model and framework. The chapter is divided in six parts: A) It begins with an overview of Future Oriented Technology Analysis (FTA) methods with emphasis on Foresight. It explains the role of foresight in understanding the future, describes briefly the various foresight methods and in more depth scenarios, weak signals and cartography of controversies methodologies. B) The second part provides a review of the main innovation process models, from an evolutionary perspective and a discussion on the differences among the various innovation types. C) This is followed by a review of technology roadmapping, as an innovation management methodology for technological innovations. D) An overview of the author's own field work in TEL roadmapping is provided, with emphasis on how this work contributed to the current 'Dynamic Roadmapping' model. E) Then, the various gaps in the literature related to foresight, roadmapping and change management are discussed from the perspective of systemic innovations at a meso (multi-organizational) level. F) Finally, the conclusions from literature review are discussed and a reflection of how these are addressed by the 'Dynamic Roadmapping model' for systemic innovations is provided.

2.1 Foresight

Foresight has developed as a very wide area of methodologies which include most of the forward future oriented activities. (Georghiou & Cassingena Harper 2013) defined *'future-oriented technology analysis' (FTA)* as methods which are trying "to apply a wider collective identity around several strategic intelligence activities including technology foresight, forecasting, intelligence, roadmapping, assessment and modelling." They acknowledge that the term *FTA* has been used interchangeably with the term *foresight*. This is evident in FTA literature. Moreover, they classify roadmapping as an FTA method, while Popper classifies roadmapping as part of a foresight method. In more traditional use of the term, foresight is an approach that provides us with several methods in order to help us anticipate uncertainty and get prepared for the future, taking into account what is the desired future for us *(a normative approach)* and/or the types of plausible futures that could be developed *(an exploratory approach)*. The methods used and their combinations vary considerably depending on the foresight planner and facilitator, the scope and the resources available.

(Saritas 2011) provides a brief analysis of the evolution of foresight. According to Saritas foresight existed already in the 16th to 18th centuries. In the 19th century, classical political economists used it in order to think about the future of capitalist economies. Trends extrapolation and social indicators methods were established in early 1900s, while Delphi and Cross impact analysis were established in mid-20th century. In the 1950s and 1960s, foresight was initially used in order to 'forecast' what will happen in the future. US department of Defence and US Navy were among the first organisations to regularly use foresight in the 1950s and 1960s. Later in early 1970s, the ability of foresight to predict the future was challenged by the unexpected oil-shocks. As a result, in the 1980s, foresight changed from predicting one future to consider and explore multiple futures. (Martin 2010) defined foresight in 1983 as a "process involved in systematically attempting to look into the long-term future of science, technology, economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits." In 2000s foresight was taken up by governments, research institutions, and other public organisations. The focus was shifted from 'scope' and 'coverage' to the actual 'process' and its participatory nature (Saritas 2011). (Miles & Michael 2002) defined foresight as "the application of 'systematic', 'participatory', 'future-intelligence-gathering and medium-to-long-term vision building process' to 'informing present day decisions and mobilising joint actions."

2.1.1 Technology Future Analysis Methods (TFA)

Porter define **TFA (Technology Future Analysis)** methods as three strategic policy intelligence methods, technology foresight, technology forecasting, and technology assessment: ''Technology foresight'' refers to a systematic process to identify future technology developments and their interactions with society and the environment for the purpose of the guiding actions designed to produce a more desirable future. ''Technology forecasting'' is the systematic process of describing the emergence, performance, features, or impacts of a technology at some time in the future. ''Technology assessment'' is concerned with the impacts of technology."

In literature, it is difficult to find consensus on the definition of the three intelligence methods, foresight, forecasting and technology assessment and what exactly they entail. It is often true that these methods use similar tools and have similar goals. (Firat et al. 2008) differentiates assessment and foresight from roadmapping methods. He claims that "assessment" and "foresight" are usually used by governments, as methods that separate thought from action, while "roadmapping" and "competitive technological intelligence" are most likely to be used by industry to link thought and action. Moreover, Industrial roadmapping (which was originated by the private sector in US) has prevailed as a method in US, while foresight; a government funded activity was used more widely in Europe.

Technology Forecasting focuses on continuous monitoring technological developments in order to identify opportunities for future applications, and assess their potential. Often these technologies are referred as "critical" for the future economy and they are assumed to be identifiable (Johnston 2008). (Tübke 2001) described technology forecasting as a three-step process, "identification - validation – information transfer and implementation" which supports decision-makers. (Coates 2004) provides a distinction between technology foresight and technology forecasting. Technology forecasting usually delivers forecasts based on mathematical models that strive for accurate predictions about the future, while foresight uses more qualitative approaches to anticipate plausible futures. Therefore, quantitative and trends analysis techniques are usually used in technology forecasting methods such as: Trends Extrapolation, Time Series Analysis, Regression Analysis, Historical Analogies, Data Mining and Literature Analysis.

Similarly to Coates, (Daim et al. 2011) agree that technology forecasting has a predictive nature *(what will happen)* in the future and when and how this probability will be assessed, while, foresight is focused more on identifying possible changes and alternative futures. The main problem that many experts and researchers see with predictive methods is that they assume *"one future"*, which can be extrapolated from historical data and models and that the stakeholders own acting will not influence it (TALEB 2008), (Tuomi 2012), (Wack 1985), (Linstone 1991), (Millett 2009), (Senge 1991). Today, we easily witness the results of overconfidence in such predictive methods applied in trading and investment banking and their catastrophic consequences in the Western economy and financial industry. Predictive methods based on past data extrapolation, are not accurate models but only approximations, which assume incremental changes and that the same forces that worked in the past will continue shaping the future and thus, challenging our interpretations on past relationships will not have an appreciative effect. In addition, strategic plans are usually need to be contextualised in very specific situations, which are unique and cannot be categorised in similar generic groups and this makes statistical predictions very difficult (Tuomi 2012). This kind of analysis results in surprises, black swans and rare events in the future, which could have never been anticipated using historical data (TALEB 2008). Moreover, looking into the future with today's lenses, we are only focusing on current constrains that might not be present in the future. For example, we are *ignoring disruptive and radical innovations*, which could have lifted the today's barriers.

Technology assessment (TA) focuses on *identifying emerging technologies and their implication*s, often by horizon scanning, and weak signals activities. Similarly to foresight, it is difficult to find consensus on a common definition for the term "Technology Assessment". The term was first introduced in the United States in 1966, by Philip Yeager and the American Office of Technology Assessment (OTA) was established in 1969–1972 in order to identify risks and benefits associated with new technologies (Tran & Daim 2008). In Europe, from the second half of 1980s to early 1990s, "Technology Assessment" was promoted by the MONITOR/FAST program and its three ECTA (European Conference on Technology Assessment) conferences. The European Parliament has founded the Scientific Technological Options Assessment (STOA) and the European Parliamentary Technology Assessment Network (EPTA). The European Technology Assessment Network (ETAN) was initiated by the European Commission. Another example was the congress "Innovations for an e-Society – Challenges for Technology Assessment" in Berlin, in 16-19 October 2001, which had a wide participation of 200 delegates from 24 countries (Rader 2001). (Johnston 2008) states that the term "technology assessment" *is often associated with parliamentary activities*. Technology assessment as an approach was first used by policy making bodies, but later was adopted by research, academia and industry (Tran & Daim 2008).

Michael Rader (Rader 2001) provides a broad definition of technology assessment:

"Technology Assessment is a form of interdisciplinary research, the results of which are intended for use in decision-making on technology.
It consists of:

- Analyses of the social, economic and ecological potentials of new scientific and technological developments;
- Analyses of the economic, legislative and social framework conditions of the introduction of scientific and technological innovation;
- Analyses of the potential positive and negative impacts of the application of new technologies.

(Rader 2001) clarifies that technology assessment does not refer to the assessment of the technology itself, but rather to a method "that organize different processes designed to compile information, evaluations and opinions from a broad range of experts and stakeholders and to present these in a form digestible by decision-makers". TA provides an analysis of possible social, economic and environmental opportunities stemming from the emerging technological developments. These developments are monitoring *via horizon scanning* techniques. The new opportunities can be driven either from technology push innovations *(technology-driven)* or from societal challenges *(problem-social needs driven)*. The resulting reports often include conflicting views, or tensions, which are resulted from differences in experts' opinions. In fact, (Rader 2001) argues that what makes such a report successful is the *inclusive analysis of all the positions and opinions of all important stakeholders, rather than achieving consensus.* The method is also used to assess the anticipating, unintended, indirect, and delayed effects of technological changes.

Tran and Daim did an extensive study in 2008 based on literature review in leading management of technology formulation journals to assess the usage of TA methods and tools. They found out that public sectors used TA methods and tools differently from private sectors. Public sector used more holistic and multifaceted research methodologies: i.e. Emerging Technology Assessment, Environmental and Integrated TA, Risk Assessment, Scenario Analysis, Impact Analysis, Structural Modelling & Systems Dynamics. While in the private sector (business and non-governmental sector) they tend to use more actionable, operational methods and tools: i.e. Mathematical models, Synthesis methods, Info. Monitoring Survey, Scenario Analysis & Delphi, Roadmapping, Technology Measurement, Decision Analysis, Cost Benefit Analysis (Tran & Daim 2008). In general, this is a common distinction that we find in the literature between TFA methods and Roadmapping, with roadmapping considered to be, unlike other TFA methods, an approach closer to market and an actionable one.

Technology Foresight is used by Governments to a) inform policy decisions, b) raise awareness of commercial opportunities for industry players and c) make researchers aware of the socio-economic impact of their research. It is also used to build consensus, and define national, regional and sectorial innovation systems (Porter et al. 2004). In Foresight studies, *the key focus is on the future development of society* compared to other two methodologies, and this is reflected on the design of the foresight projects, which usually are based in scenario methodologies and backcasting (Carlsen et al. 2010). Technology Foresight as an approach addresses the impact of technology development on a broader scale than the

Technology Forecasting and Technology Assessment methods. This implies the involvement of *a diverse range of stakeholders*, rather just experts. The stakeholders assess the impact of Political, Economic, Social, Technological, Environmental and Legal (PESTEL) drivers and provide recommendations in order to support *policy decisions* at local, regional, national and sometimes international levels.

2.1.2 The role of foresight in understanding the future

"To create the future, you must first of all be capable of imagining it" Gary Hamel
"life happens when you make other plans" a life says

In their book "2004 State of the Future" (Glenn & Gordon 2004) provided insights on the basic assumptions behind our understanding of the future:

- "You cannot know the future, but a range of possible futures can be known.
- The likelihood of a future event or a condition can be changed by policy, and policy consequences can be forecasted.
- No single method should be trusted; hence, cross referencing methods improves foresight.
- Humans will have more influence on the future than they did in the past."

Foresight emerged in decision-making contexts following the Second World War in fields such as US military strategic planning, with the RAND Corporation and in French spatial planning, with DATAR (the National Institute for Spatial Planning). In the 1960s, General Electric and Royal Dutch/ Shell introduced foresight techniques in their corporate planning procedures. In the 1970s, foresight included scenarios of socio-economic and environmental futures, in an attempt to introduce the first global models that tried to address these issues in an integrated fashion. Foresight is concerned with investigating a variety of possible futures. Most importantly, it is focused on *creating desirable futures through the actions we choose to take today*. We could argue that foresight provides a better understanding of the key concepts and their relationships/dependencies in the particular domain, initiates strategic conversations between key actors and stakeholders, and maps their agreements, disagreements and commitment to act upon collective solutions. Thus, successful foresight is a collaborative and iterative process. Figure 1 depicts foresight as a combination of three functions: Planning, Futures and Networking (Leonie Project 2005) (Miles 2002). In this illustration, foresight is a participatory approach, where networks use social networking tools and other participatory group work in order to agree on common visions, stress-test these visions under a number of future scenarios and create strategic plans for the visions' realisation.

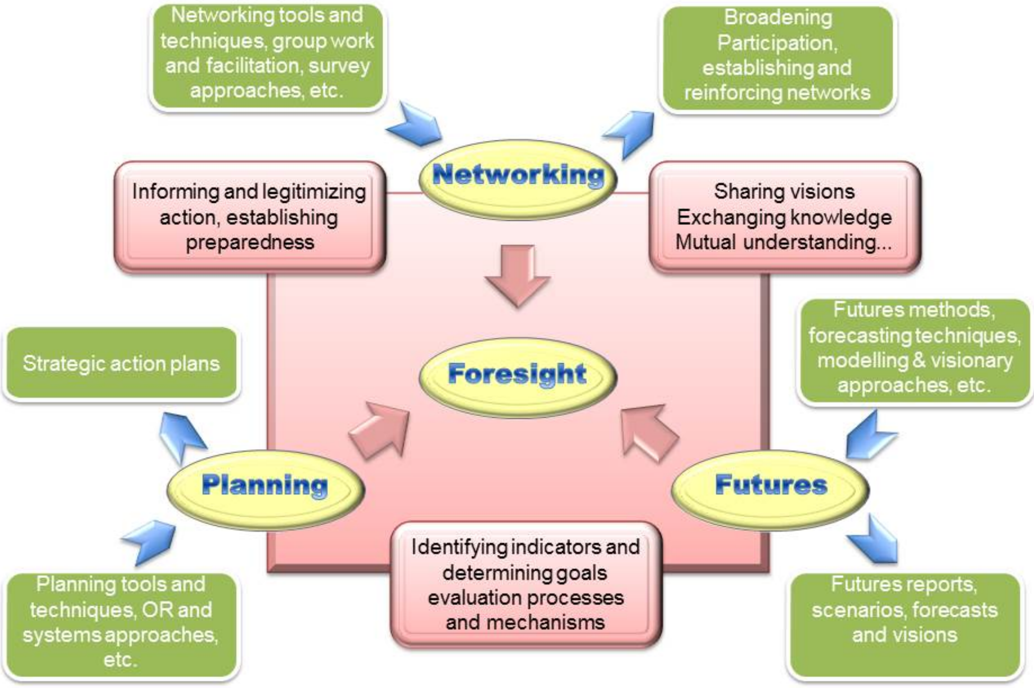

Figure 1. Foresight cornerstones. Adapted from (Leonie Project 2005) from figure 3, p.18

Foresight approach can be seen as causing a shift in strategic planning from rational approach to more evolutionary participative approaches, and from predictive models to more exploratory approaches. These approaches recognise high levels of uncertainty as the norm in strategic planning. The importance of disruptive innovations in economic progress is also highly valued. The exploratory approaches are usually based on iterative pictures of plausible future contexts. The early involvement of stakeholders in collaborative exploration of these future contexts is very important. This shift in strategic planning causes a shift in policy development from top-down expert based approaches to a broader stakeholders' involvement and the involvement of other social groups. Since, knowledge today is more widely distributed, this is reflected on the way of networking and gathering the intelligence needed to plan policies (Keenan & Koi-Ova 2003).

In addition, some (Keller & von der Gracht 2014) believe that the increasingly use of ICT tools in foresight exercises will cause foresight methodologies to shift from *horizon scanning and data retrieval approaches* to more *qualitative methodologies* focused on interpretation, decision making and implementation. ICT tools will make foresight processes more effective by providing better accessibility to large size of information, easy to use collaborative tools including collaborative modelling tools, interlinked knowledge banks, which will support better and more accurate insights of the future. Nevertheless, foresight will remain a social creative learning process. The ICT tools will have a supportive role.

The IPTS JRC EU FOR-LEARN project (FOR-LEARN 2006) *identified three basic functions of Foresight methods* :

- *Diagnosis:* Understanding where we are (methods associated: scope of the issues, environmental Scanning and trend extrapolation)

- *Prognosis:* Foreseeing what could happen (methods associated: scenario building, creativity methods and Delphi)

- *Prescription:* Deciding what should be done (methods associated with roadmapping, backcasting, modelling and simulation)

2.1.3 Foresight Methods

There are many different methods and tools, which can be combined in different ways that can be used in foresight exercises. (Coates et al. 2001) as summarized by (Firat et al. 2008) has identified nine broad families of foresight methods: Expert Opinion, Trend Analysis, Monitoring & Intelligence, Modeling & Simulation, Scenarios, Statistical, Descriptive, Creativity, and Valuing/Decision/Economics Methods. Gordon & Glenn (2003) as summarised by (Firat et al. 2008) listed the methods most often used in each of these clusters.

- Expert Opinion: (Delphi, Focus Groups, Interviews, Participatory Techniques)

- Trend Analysis: (Trend Extrapolation & Growth Curves, Trend Impact Analysis, Precursor Analysis, Long Wave Analysis, Monitoring and Intelligence Methods, Monitoring)

- Bibliometric: (research profiling; patent analysis, text mining)

- Statistical Methods: (Correlation Analysis, Demographics, Cross Impact Analysis, Risk Analysis, Bibliometric)

- Modeling and Simulation: (Agent Modeling, Cross Impact Analysis, Life Cycle Analysis), Causal Models, Diffusion Modeling, Complex Adaptive System Modeling (CAS), Systems Simulation, Technological Substitution, Scenario-simulation, Economic base Modeling, Technology Assessment)

- Scenarios: Scenarios, Scenario-simulation (gaming), Field Anomaly Relaxation Method

- Valuing/Decision/Economics Methods (Relevance Trees, Action Analysis, Cost-benefit analysis, Decision analysis, Economic base Modeling)

- Descriptive and Matrices Methods: (Analogies, Backcasting, Checklist for Impact Identification, Innovation System Modeling, Institutional Analysis, Mitigation Analysis, Morphological Analysis, Roadmapping, Social Impact Assessment, Multiple perspectives assessment, Organizational analysis, Requirements needs analysis,

- Creativity: Brainstorming, Creativity Workshops, TRIZ, Vision Generation, Science Fiction Analysis)

(Popper 2008) presented the results of an analysis of the European Foresight Monitoring Network (EFMN) database (800 exercises) at the 3rd International Conference on Foresight, in Tokyo in November 2007. According to this study (Popper 2008) the most widely used methods are literature review (477), expert panels (440) and scenarios (372). Other commonly used methods are futures workshops (216), brainstorming (157). Trends extrapolation (223), interviews (154), questionnaire surveys (133), Delphi (137), Key technologies (133), SWOT analysis (101), technology roadmapping (72) and modelling and simulation (67). Less widely used methods include stakeholders mapping (46), citizens panels (19), cross impact/structural analysis (36), games (6), Bibliometric (22), backcasting (47). As expected, Foresight is predominantly seen as a mixture of literature review, expert's panels and scenarios. It is interesting that bibliometric and other data mining methodologies had limited used in 2008. It is expected that the more recent 'big data' trend will significantly change this score. In addition, the same trend is expected to significantly increase the use of cross-impact analysis based on Bayesian probabilities, a method that also scored a law number in Popper's study (36). For example, computational algorithms could enable the generation of very large number of scenarios, combined with Bayesian probabilistic methods in order to reduce their number as more information is becoming available (Dong et al. 2013). According Popper's study, roadmapping and weak signals were also rarely used as foresight methods.

Figure 2 shows a widely used example of foresight categorization made by (Popper 2009). This categorisation was based on a survey of more than 2.000 foresight studies of the EFMN database. This taxonomy of foresight methods, called Popper's diamond of foresight is based on the a) *nature of resources* and the *b) capabilities in gathering, processing and analysing information.* He identified four main types of capabilities *'creativity'* versus *'Evidence'*, and *'Expertise'* versus *'Interaction'*. *Creativity methods* are depending on the imagination, creativity and ingenuity of experts and technology gurus, while *evidence methods* are depending on codified data, and indicators. *Expertise based methods* are usually top-down methods, influenced by experiences, skills and knowledge sharing of subject experts and professionals, while *Interaction methods* are usually bottom-up participatory approaches, influenced by discussions and knowledge exchange among experts, and other stakeholders. Methods according to the nature of resources are classified as *Quantitative* (apply statistical analysis), *Qualitative* (apply sense making to events and perceptions) and *Semi-quantitative* (apply mathematical principles in order to quantify expert opinions) (Popper 2008), (Popper 2009), (Turturean 2011).

In Popper's diamond, we see that roadmapping approach is considered as a type of foresight method. It is classified as a Semi-Quantitative method based on expertise and knowledge sharing. Also, been closer to 'expertise' is rather viewed as an expert-based top-down approach. We also can argue that such classification of roadmapping relates more to *1st generation of roadmaps* addressing linear innovations at micro (company) and macro (industry-sector-policy) levels, where experts can make more accurate predictions about technology evolutions (For a more detailed analysis of roadmaps generation, see also section 2.3.9). According to (Popper 2008) roadmapping is sometimes applied in action phase as a bridge between foresight planning and actions implementation. But, as such, it seems more like a one-off activity rather than a continuous process, which would provide monitoring and updating. It also seems that foresight is done first as an independent study and then roadmapping follows.

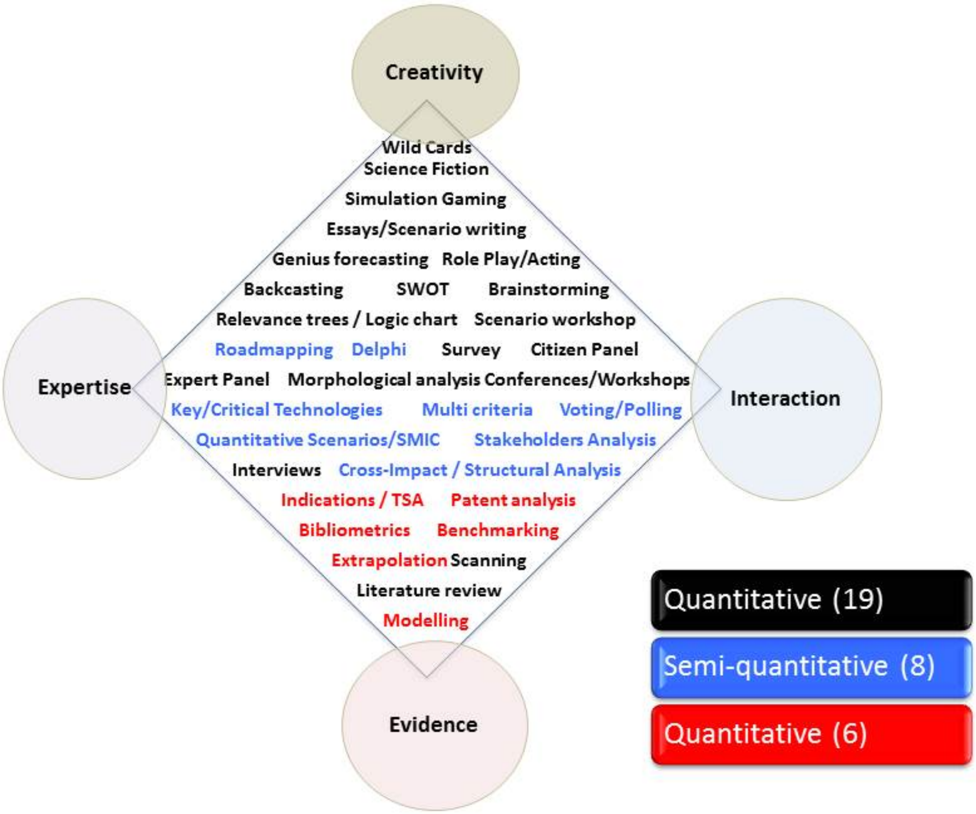

Figure 2: Categorization of foresight methods according to Popper's Diamond. Adapted from (Popper 2009) from Figure 5.1, p.72.

Foresight phases

According to (Popper 2008) & (Miles 2002) foresight consist of *five interconnected phases*: Pre-foresight phase (Scoping) ; Recruitment phase (forming the team); Generation phase (exploration, analysis, anticipation); Action stage (planning actions, advisory, informing) ; Renewal phase (learning, education, dissemination).

(Saritas 2011) considers foresight as a systemic process, which aims to understand complex systems and their behaviours. In 2010, he provided a different classification for foresight phases based on the systems thinking approach. This systemic thinking is also applied in the Dynamic Roadmapping model and framework (Sections 3.1.3, 3.1.4 describe the theoretical grounding of Dynamic roadmapping according to systems approach).

(Saritas 2011) proposes 5 basic "mental acts":

1. *Systemic understanding.* Systemic understanding refers to understanding of the situations and issues of the influential actors of the system within their own context

and the uncovering of the values, and preferences of actors and stakeholders. Methods at these stages could be modelling and weak signals.

2. *Systems synthesis and modelling.* Systems synthesis and modelling, refers to a shared understanding of alternative images of the futures and the corresponding range of possible, plausible and desirable future systems. Methods such as Modelling, Scenario Planning, Gaming, and Simulation are the methods which may be of help to explore alternative futures are used in this stage.

3. *Systemic analysis and selection.* This refers to the systemic analysis of the plausible futures and selection of the most desirable one. Methods used are Delphi, Cross Impact Analysis, Multi-Criteria Analysis, SWOT and/or Cost/Benefit/Risk Analysis

4. *Systemic transformation.* It refers to the transformation strategies needed for connecting of the most desirable future to the future: Assessment, Leadership, Linking strategic and operational change, Management of human resources. Roadmapping methods are used to define the transformation process in the long, medium and short run.

5. *Systemic action.* Refers to coherence (*e.g*. achieving the consistency of goals, creating an adaptive response to environment; and maintaining competitive advantage). Action Plans, Operational Plans, Priority Lists, Critical/Key Technologies can be among the outputs produced at this stage.

Recognising also foresight as a systemic methodology, Aaltonen M., (2009) as cited by (Turturean 2011) has provided a classification for foresight methods according to *four criteria* (Mathematical complexity; Social complexity; Engineering Approaches; and Systems Thinking) and *two dimensions* (according to the nature of possible understandings of systems and Means of controlling or directing systems). Figure 3 below shows this classification.

The differences between the four approaches are presented by combining a horizontal dimension *'Means of controlling or directing the systems'* with a vertical dimension *'Nature of possible understanding of the system'*:

In the vertical dimension *'Nature of possible understanding of the system'*, *'design'* means the manager, group, expert or researcher is able to stand outside the system and design it as a whole. With 'emergent systems', the foresight group, expert, manager, use 'mathematical complexity' approaches in order to reduce systems complexity. In this case, the system is impossible to be predefined and understood or influenced by a single group, a single company or any experts, since it is emerging through the interaction of the system agents (people, processes, technology, government etc.), who make decisions and based their actions on localised knowledge and their own principles. In the horizontal dimension *'Means of controlling or directing the system'*, a distinction is made between 'rules' (or process) that eliminate ambiguity versus 'heuristics' (or values) that allow ambiguity in order to provide direction which can be contextualised.

‘*Emergent*’ systems have a design element in the sense that the agents can influence the system with their own acting, but it cannot be achieved by any agent alone. In contrast, in ‘*Design*’ systems, an agent can influence and manage the system by themselves. In this classification, roadmapping is again a method fitting for well-structured systems that are characterised by low uncertainty. This preconditions the existence of dominant technological designs, strong trends, and stable product technology platforms. This classification depicts roadmaps as method for managing incremental innovations, which can be managed by a single agent. Moreover, scenarios and cross impact analysis seem to be methods that integrate Engineering and systems thinking approaches, while visioning is used for managing social complexity in the sense that the actors own actions and visions can influence their futures. The ‘Dynamic roadmapping model’ integrates foresight, roadmapping and visioning approaches in order to provide a methodology to address the gap for dealing with complex domains and systemic innovations (e.g. innovations driven from socio-economic and technical changes). The assumption is that in complex domains and systemic innovations a single agent alone cannot manage the design, development and adoption of the innovations.

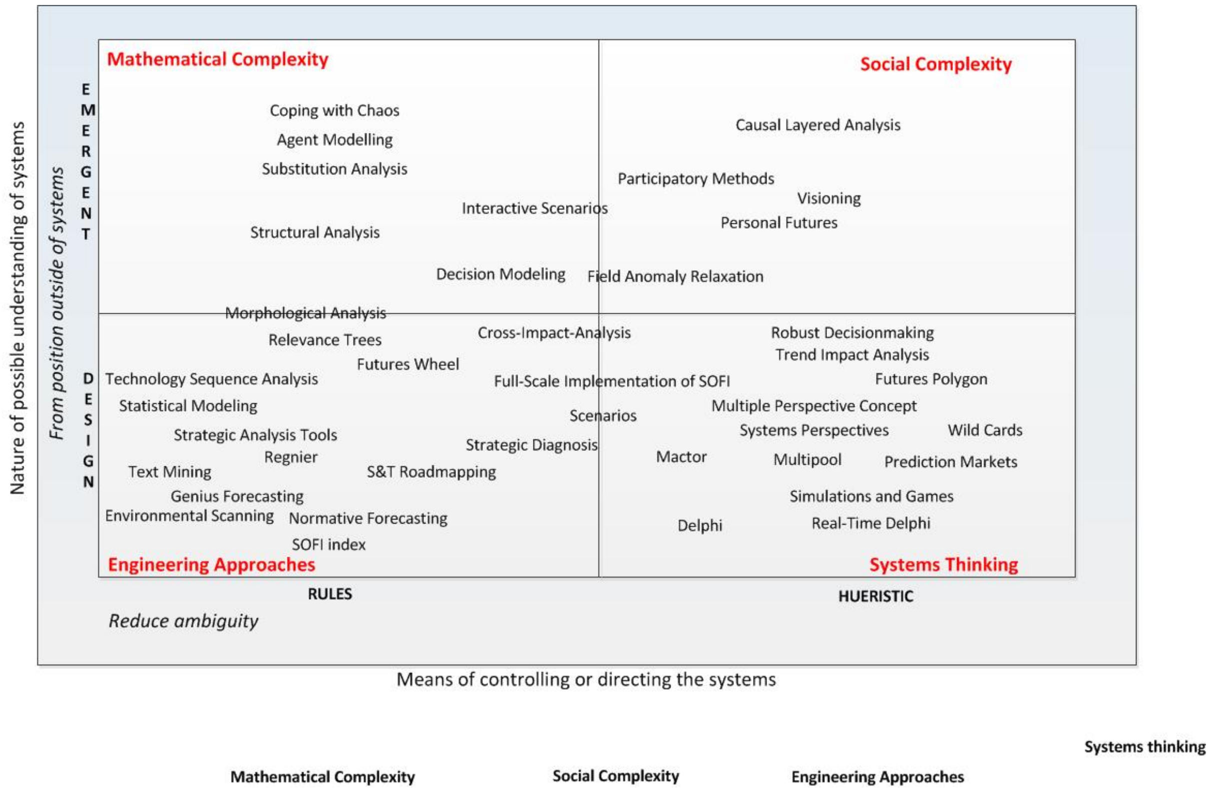

Figure 3: classifications of foresight methods according to Turturean. Figure adapted from (Turturean 2011) from figure 6, p. 119.

According to (Barré 2001) foresight exercise consists fundamentally of a succession of “extension” and “concentration” steps. The foresight participants engage in interactive activities consisting of an exploration and hypothesis-building stage (extension), followed by a selection-, convergence-, and synthesis stage-concentration.

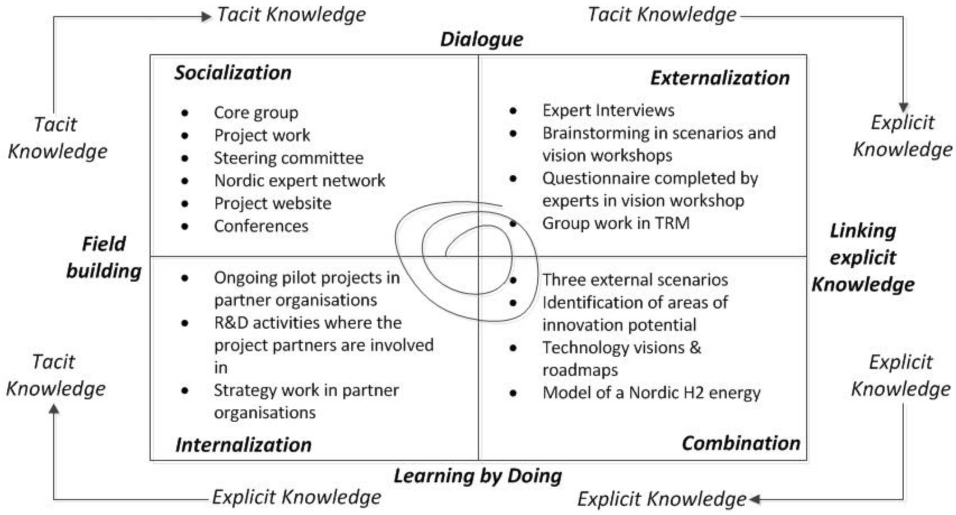

Figure 4: Stages using Nonaka's SECI Model. Figure adapted from (Eerola & Jørgensen 2002) from figure 2, p.12.

This approach was adopted by Prolearn roadmap for Technology Enhanced Professional Learning (Kamtsiou et al. 2006), (Naeve et al. 2006), (Kamtsiou et al. 2005), (Kamtsiou & Naeve 2008). In such approach, Foresight methodologies are ways by which the extension and concentration steps are carried out. In Prolearn, such approach recognised Roadmapping as a learning process form tacit (implicit vision) to codified (expressed vision statements) knowledge transformation cycles. (Eerola & Jørgensen 2002) argues that technology foresight exercises are useful tools for shared knowledge creation; therefore, participative knowledge creation theories, such as Nonaka's SECI model for knowledge creation could be used for mapping the foresight processes (see Figure 4). In this method, shared knowledge creation is explained as a spiral process during which, knew knowledge is created via the interaction between tacit and explicit knowledge. There are four different modes of knowledge conversion i.e. socialisation, externalisation, combination and internalisation which also play a key role in knowledge conversion. SECI framework creation model is one of the theories that provide the theoretical grounding of the 'Dynamic Roadmapping' model (see theoretical grounding of the Dynamic Roadmapping model in also Chapter 3.)

2.1.4 Future Scenarios

Durance & Godet (2010) (Durance & Godet 2010) specify that there are 3 main approaches for scenario building. The first approach to ever introduce scenario-development was developed by Herman Kahn in US in the 60s during his work at the Rand Corporation. The second was developed by Has Ozbekhan and the 3rd by a French governmental foresight department from the late 60s to early 70s. Khan and Wiener (2000) as cited by (Durance & Godet 2010) have defined scenarios as a "hypothetical events' which are set in sometime in the future in order to clarify a possible chain of causal events, as well as their decision points. This implies stories of possible futures, which have been shaped by a set of key events between the present and the scenario time in the future. He also identified five simultaneous conditions that must be considered i.e., pertinence, coherence, likelihood, importance, and transparency. In Rand, they have also developed the *Delphi technique*, which was based on experts' opinions about the probability of certain events to happen in the future and their perceived impact if they happen. Then, the experts were asked to consider and compare each other's views with the aim to reach a consensus at the end.

Following his work in Rand, Kahn founded the Hudson Institute, in mid 60s, to further develop his scenario approach. The aim of this approach was not to predict the future, but to consider "unthinkable futures". In 1947, the SRI (Stanford Research Institute) was founded in US with the aim to provide future planning approaches to US firms. Due to the Vietnam War, and the social and economic changes it brought to US, this approach was later viewed as a way to provide long term planning that could make changes in society. Meanwhile, Shell, a corporate sponsor of Hudson institute, started to introduce this scenario thinking approach in its own corporation. From early 80s General Electric (GE) started using scenarios in their future analysis for understanding how environmental factors could influence their business. They have used literature reviews and the Delphi method developed in RAND, in order to identify trends and critical indicators as potential future events. In parallel, they were the first to use *trend-impact* analysis and *cross-impact* analysis in order to assess the impact of interactions of various factors and indicators. The results were used to create probable scenarios for the environment. Shell Corporation (The Royal /Shell group) was another company that helped to establish the scenario methodologies of today. They have used scenario planning as a method for strategic planning to assist decision making. This method helped them to successfully cope with the oil crisis in 1973 and 1979. By late 1980s Shell *integrated scenario planning* into the company's annual strategic and business planning, which was also extended to the company's line managers. Shell's method of *Intuitive Logic School* is based on the identification of factors such as trends, tensions, or other events that might be highly uncertain, but they will have a high impact (positive or negative) on the future in case they do realise.

There is a long standing lively debate whether quantitative methods (extrapolations from past trends) should ever be assigned to scenarios. The first generation of scenario planners at SRI International, Shell, and Global Business Network (GBN) were completely against the idea that probabilities should be used with scenarios. These kinds of scenarios wanted to encourage flexible, positive rather than deterministic planning: "You can't predict the future." The uncertainties of the future are better addressed by multiple and equally plausible scenarios rather than either traditional quantitative forecasts or single "most likely" scenarios.

Wack in 1985 as cited by (Bishop et al. 2007) changed the fundamental definition of a scenario from Kahn's *hypothetical sequence of events* from the present to the future ('future now' technique), to *alternative future states* regardless of the steps needed for the future states to be achieved. He developed the 'Intuitive Logics' approach, which was later practiced by SRI and Shell. It was also further developed by the Global Business Network (GBN) headed by Peter Schwartz. Kahn as cited by (Bishop et al. 2007) stressed that his scenarios were strictly hypothetical and not predictive. Therefore, Kahn had did not use probabilities in his scenarios. Wilson's team at General Electric (GE) generated four alternative futures for the U.S. domestic consumer market by 1980, while Wack's team generated two alternative futures for international oil to the year 2000. Wilson's team applied intuitive probabilities to their GE scenarios, but Wack's team did not. (Bishop et al. 2007) argues that a good scenario grabs us by the collar and says, "Take a good look at this future. This could be your future. Are you going to be ready?" According to the authors a scenario is the archetypical product of futures studies because it embodies the central principles of the discipline:

- It is vitally important that we think deeply and creatively about the future, or else we run the risk of being surprised and unprepared.
- At the same time, the future is uncertain, so we must prepare for multiple plausible futures, not just the one we expect to happen.

Scenarios seem fit *to capture disruptive changes*, using intuition, imagination, and story qualities. In addition, as a strategic intelligence planning tool, scenarios capture and explore many possible outcomes in the future and not just one, which is the biggest criticism, when using probabilities to develop scenarios in a predictive manner.

Exploratory versus normative scenarios

Exploratory (or context) scenarios (what might be) are starting from the present and trying to explore possible futures through the analysis of trends and other drivers. They do not aiming at a predetermined desirable future state, therefore they are not containing human values. While, *normative scenarios (what ought to be)* are starting from the future whether desirable or feared and then lead back to today, therefore they include human values, wishes and desires. In this sense, we need to imagine the future first and then identify the events that led us to it. The exploratory scenarios are seeking to answer *'What if'* questions, e.g. "what if the growth rate is x% or y%? What if events W or Z happen? What if we pursue one or other strategy? They combine usually trend, impact, and *cross-impact analyses, and Delphi methods* (Keenan & Koi-Ova 2003).

Normative scenarios are asking the question *'How'*, for example "what would it have taken to have reached a future where the parameter of interest is x% greater than its current value? What would have led to situation Y" (Keenan & Koi-Ova 2003)? Usually look at the events and trends that could lead us to the desired future. Methods often used are *learning cafe workshops, visioning and morphological analysis*. Normative (or visionary) scenarios are pictures of desired futures. (Burke 2009) stresses that conversations at the scenario development process cannot be strategic, as participants will feel that they are being controlled; conversations should focus on desired or preferred futures and not on strategic futures, which have a competitive nature and are based on current positions which are only reflect anxieties of today and the possibilities or constrains of the present projected in the future. Konnola also adds that "Reports from recent foresight projects, in turn, have emphasized **the importance of common vision** building as a step towards the synchronization of the innovation system. In these developments, the locus of foresight activities has tended to shift from positivist and rationalist technology focused approaches towards the recognition of broader concerns that encompass the entire innovation system, including its environmental, social and economic dimensions" (Könnölä 2007).

(Cho 2013) makes his own comparison between the exploratory scenarios and normative scenarios. Exploratory scenarios are characterised as being evolve on a *predetermined S-shaped curve*; they are too naïve: they project anticipated consequences and they are suggest alternatives to the proposed allocation. In comparison, normative scenarios are characterised as been more proactive; too complex and mathematically intricate; meaningfulness of its treatments of goals is significant; provide recognition of economic potential; they are recognised for their responsibility towards society or nation; they improve awareness of constraints (natural resources, company resources, etc.); and recognition of an ultimate technological potential; and hedging against threats.

Millet defines 'Futuring' as "a systematic process of thinking about the future in order to frame reasonable expectations, to identify emerging opportunities and threats to the company or to an organization, and to anticipate actions that will promote desired outcomes….One thinks through the problem from the macroscopic, external environment to the microscopic factors of a company or organization… 'Visioning' is the opposite of Futuring: it is a logical process that progresses from the micro- to the macro-levels" (Millett 2006). "Futuring" is an exploratory approach that looks at plausible futures based on an analysis of trends, and issues in the larger world, many of which are beyond our immediate control, while "visioning" is a normative approach which focuses on plans and actions to make desired outcomes possible.

In 'Dynamic Roadmapping' approach, both scenario types were used and integrated. Normative scenarios help the roadmapping group to agree on a shared desired vision as a common visionary framework for their future. This approach helps focus the group on desired systemic change, while it reveals their assumptions made about the future. Context scenarios, on the other hand, are essentially, representations of different types of developments, based on anticipated changes and uncertainties in PESTLE drivers, which could impact the realisation of their visions. The exploratory context scenarios approach is used in order to test and monitor the efficiency and effectiveness of both, the visions and the associated roadmaps to achieve them. The roadmaps are the visual representations of how the visions will be achieved. They are developed starting from the high level visions, towards more contextualised specific goals, in order to operationalise the foresight results and make them actionable.

Exploratory or Context Scenarios

For practical purposes, it is a challenge to identify a small number of scenarios that can effectively provide an overview of the future states in different contexts and cover the main topics of interest that are important to investigate in the future analysis. As mentioned before, Royal Dutch Shell and SRI International developed in parallel the context scenario-planning, as an approach that starts by identifying the key future uncertainties as external forces, drivers, trends, signals and in general factors that could influence the future. Then, these key axes of uncertainties are reduced to a small number of usually 2 key polarities (or tensions from key drivers of change), which then form a 2 by 2 scenario matrix. This matrix reduces the context scenarios of key uncertainties for the future (Wilson & Ralston 2006).

(Ratcliffe 2006) developed an approach based on the Prospective method. This approach is called *'Strategic Prospective through Scenarios Thinking'* (see Figure 5), which uses aspects from the French prospective methodology and from Anglo-American scenario planning techniques. This approach first identifies events that might have some impact on the future or issue at hand and whether, if the event happens, will have a high or low impact. Gaston Berger, one of the founders of the prospective school developed at France, listed the main principles of such approach:

- to look far away, as prospective is a long-term activity
- to look breadthways, in order to examine interactions
- to look in-depth, so as to become aware of the most important trends and issues
- to take risks, because new adventures can lead to the change of long-term plans; and
- to take care of humanity, as prospective should fundamentally be concerned with implications for people.

According to Ratcliffe, the results from the uncertainty analysis and the prospective, scenarios can be used as powerful tools for strategic policy analysis, especially in cases where policy-makers have fragmented, unstructured and biased information. He argues that they provide a comprehensive, clear and accessible insight for the politicians of how policy options might play out in various different futures (Ratcliffe 2006).

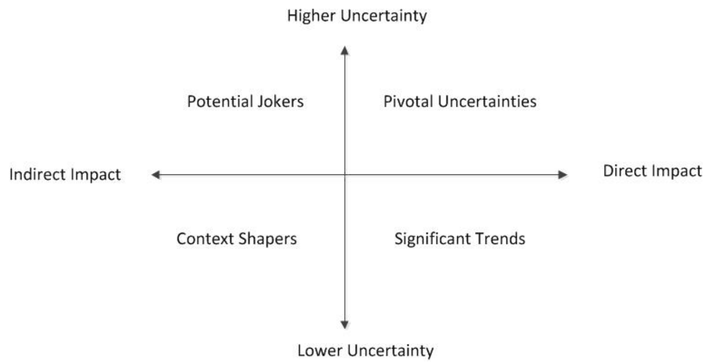

Figure 5: Ratcliffe Scenario Matrix. Figure adapted from (Ratcliffe 2006) Exhibit 2,p.4.

Adam Kahane, in his book "Transformative scenario planning" (Kahane 2012) has also provided an alternative method of scenario development focused on exploratory scenarios. He proposed a scenario planning approach based on 6 steps: 1) Convene a team from across the whole system (Coinitating), 2) Observe what is happening (Cosensing), 3) Construct stories about what could happen (exploratory scenarios), 4) Discover what can and must be done (copresencing) 5)Act to transform the system (Cocreating), Coevolving (see Figure 6).

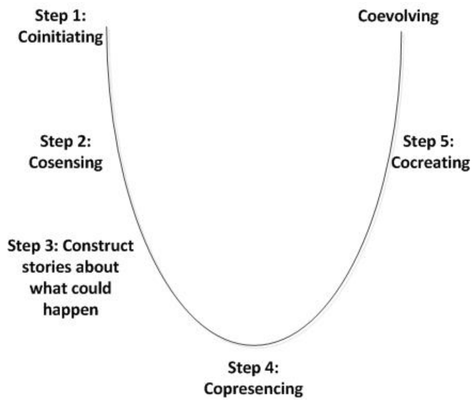

Figure 6: steps of Transforming Scenario Planning. Figure adapted from (Kahane 2012) from figure 5, p. 23)

Through his first step (Convene a team from across the whole system) he recognises the need to bring enough people together in order to have enough diversity to capture the whole system insight and influence. He claims that this should be about 25-35 people. This principle is similar to the Future Search Conference (FSC) principle "bring the whole system in a room", which has also been adapted by the 'Dynamic Roadmapping' model. For a description of FSC approach see section 2.1.7. Sections section 4.1.1, 6.5.1 &7.4 describe how FCS has been modified and applied in 'Dynamic Roadmapping' model. Kahane also recognised that this is a lengthy approach, with workshops stretch to 3 to 4 days each and the whole process lasting about 8 months. The second step (observe what is happening), is similar to the '*Dynamic Roadmapping'* approach of creating a domain cartography. In the 'Dynamic Roadmapping' approach, the cartography also assists in enhancing the membership of the co-innovation group, by linking together similar minded actors via common and complemented activities, who build the desired scenarios and the roadmaps. Therefore, both approaches: top-down (which ensures that all necessary stakeholders' roles are included) and bottom up (which ensures that people with same objectives and interests are aligning their plans for a common desired future, without forcing an artificial consensus) are used in order to form the scenario group. Contrary, in Kahane's case, it seems that 5-10 people form the scenario group in a top-down way. In step three (construct stories about what could happen) the participants create context scenarios, using a 2 by 2 matrix developed by the two axis of key uncertainties. This is a similar approach to the approach used in the 'Dynamic Roadmapping' for developing the context scenarios. In step four (discover what can and must be done) the scenario group identifies actions that they could take to either adapt to the system or influence it, and in step five (act to transform the system) the scenario participants make plans to operationalise their actions. Although Coevolving mentioned in his model as next step, he does not provide any process or guidelines for this step. His model stops at step 5. Unlike the 'Dynamic Roadmapping' approach, in Kahane's mode the visionary scenarios are not developed separately, but they are implied in step 4 and 5. This implies that the participants are expected to come up with actions that would influence the future towards their desired directions. In the 'Dynamic Roadmapping' methodology the co-innovation group, develops their desired scenarios in the very beginning in order to express a combined high level vision that comprise the group's desirable change for the system, which would not be tied to today's anxieties, existing capabilities and trends. In addition, the actions are co-evolving via an observatory that provides alerts for future updates, based on which new actions are planned. Finally, in order to achieve a true transformation of the system, the whole process should be recognised as a participatory learning process that expands both the knowledge and practices of the roadmapping participants and the system they are trying to influence. To that respect, the expansive learning (CHAT theory) and SECI framework for knowledge creation are theories that applied to 'Dynamic Roadmapping' approach (See also Chapter 4: theoretical grounding of the approach).

(Porter 1980) has also recognised scenarios as an important tool for strategic planning and for sensitivity analysis for the firms. Under this approach, three scenarios were developed about the future: one optimistic, one neutral and one pessimistic. Porter saw scenarios as pictures of possible future outcomes rather than forecasts. He also developed the 'five forces of competitive position model' as a strategic planning tool for firms, in order to enable them to understand the forces in their markets and assess and analyse their competitive power and position in the domain. These five forces are; existing competitive rivalry between suppliers; threat of new market entrants; bargaining power of buyers; power of suppliers; threat of substitute products . 'Dynamic Roadmapping' model recognise the need to account for *suppliers and buyers bargaining power as well as other intermediaries*. Porter's model seems to treat buyers, competitors, and suppliers as unrelated entities, who do not interact with each other. It also assumes incremental slow changes, which would allow the firms to make long term plans, rather than rapid radical changes. Systemic innovations require the systematic coordination of the contributions of various players such as buyers, suppliers, co-innovators, intermediaries and customers. 'Dynamic Roadmapping' accounts for this need by *integrating change management techniques*, and more specifically *Adner's model* of *'innovation blueprints'* (Adner 2002) for supporting the adoption of innovations (see also Section 2.4.7).

2.1.5 Cross-Impact Analysis & Bayesian Probabilities: Alternative Scenario Methods

Cross-Impact Analysis and Bayesian Probabilities were developed in the late 70s as an answer to the criticisms about quantitative methods based on historical data. These approaches consider observations (such as experts' beliefs, issues, factors, drivers, weak signals, wild cards, trends) about how future events may change perceptions based on historical data and predominant trends. They are starting with the identification of key potential issues, most of the times based on previous knowledge, intuition, and expectations, and examine their probabilities and their impacts, using expert values and Bayesian probabilities methods (Millett 2009).

According to the handbook of Knowledge Society Foresight (Keenan & Koi-Ova 2003) the most frequently used probabilistic approach in the field of social analysis is *the Bayesian approach*, in which probabilities are interpreted as subjective *'degrees of beliefs'*. This approach is concerned with conditional probability, in which, it tell us the probability of a hypothesis or a Belief is true if an event happens. The condition is the event that happened, for example, how likely is that our hypothesis is true, given that such event has occurred? This approach is often used in futures and foresight analysis, where the analyst or a group of experts considers a particular value for the different variables. Bayesian probability-based methods thus, give an indication of the likelihood of outputs dependent on the subjective likelihood attached to the uncertainty model input or parameters. In this approach, an initial probability is assigned about an event based on a subjective value, and then it is continuously adjusted (*a posteriori*) according to new information, up to the final moment of arrival at a target date in the future (Silver 2013).

Cross-impact analysis methods, originally developed by Theodore Gordon and Olaf Helmer in 1966, address the basic limitation of many forecasting methods such as the ***Delphi method*** which produce only isolated forecasts; In Delphi, Events and trends are projected one by one, without explicit reference to their possible influence on each other (information about mutually exclusive or conflicting outcomes). Most events and developments however, are in some way connected to each other, and an event happens because some other events influenced somehow its occurrence or caused it. This interrelationship between events is called Cross-impact. Cross-impact analysis addresses this problem directly by analysing conditional probabilities -for example, the likelihood that inflation will be low if full employment is achieved. Interdependencies between these events and developments can be taken into consideration for more consistent and accurate understanding of the possible future. Two steps are involved in cross impact analysis. 1st experts are asked (via interviews, questionnaires and workshops) to assign a probability of occurrence to an event (p). Then in step 2, the experts are asked to estimate the conditional probabilities asking questions such as if an event x occurs what is the probability of event p to occur (Gordon 2004).

According to (Millett 2006) analytical *scenarios based on modelling, cross-impact analysis, and Bayesian probabilities* allow teams and executives to better understand the conditionality of any scenario and determine what would have to happen to improve the probability that the most desirable scenario could be made to happen. In other words, the use of probabilities facilitates strategy development by examining different conditions and their likely outcomes given different resource commitments. In this light, Probability-based methods only address uncertainty in model quantities and ignore uncertainty in model structures. It helps assess which elements/parts in the scenarios or roadmaps could be implemented in short terms, and which are planned for longer term, when more information becomes available.

2.1.6 Trends and Weak Signals Analysis

The introduction of a debate around *wild cards and weak signals* in Technology Foresight can foster lateral thinking, which can help decision-makers evaluate different aspects of a decision and business environment. The objective of these methodologies is to create a convergence of the belief in the subjective probabilities held by different individuals on a particular subject and take actions, while classifying areas for collecting intelligence for key uncertainties and drivers. Similarly to Bayesian method, the end goal is that the initial subjective probability should be adjusted continuously and get more and more closer to the actual real probability as more information are becoming available. Therefore, it is a learning process (Keenan & Koi-Ova 2003).

Conceptually speaking *in the 'Dynamic Roadmapping' model*, typical foresight methods (trend analysis, scenario analysis, weak signal analysis) can be seen as part of *Roadmapping intelligence*, which drives the knowledge creation in Roadmapping groups. In this approach scenarios are used as the predominant method to define the future states. They are also complement the with weak signal analysis in order to take into account aspects about the future (at both micro and macro levels) that might otherwise be dismissed as possible because they might not be considered attractive. Or they might have to be overlooked, since they are not regularly associated with the particular sector or domain.

The objective of *the Weak Signal Analysis* is to capture divergent or creative signals or points of view. Weak signals are events under the surface which might be overlooked, but, nevertheless, might turn out to cause a major change. Most approaches, however, fail to observe or record such signals, and dismiss them because the most typical evaluation techniques allow for identifying only strong trends. Also at sector-levels, weak signals that are related to disruptive innovations are usually not observable by incumbent firms. This is because established firms, unlike start-ups firms, who are responsible for disruptive innovations, they focus more on factors, which support incremental innovations, thus they tend to look for signals that reimburse existing beliefs and mental models.

Weak signal analysis is used in order to take into account observations (issues, factors, conflicts, weak signals, trends) about how recent changes may affect the future, based on an investigation on the key uncertainties and their impact as they are perceived today. In this case, and specifically building on the weak signal approach, a list of proposals can be devised to answer questions about the policies and actions, which could be put in place in order to get an indication about the Probability, Feasibility, Desirability and importance of future events and what this would mean for the scenarios and actions. It is a tool to analyse a possible impact of these events in the development of the future visions. This method is also a good approach to compliment the scenarios methods in terms of avoiding wishful thinking mentalities and dismissing of scenarios that are probable, but not perceived as desirable. As depicted in the Figure 7 below, the uncertainties are assessed according to their perceived impact and likelihood to happen. Factors, trends and other issues are classified according to their degree of certainty of occurrence and the degree of direct impact on the scenarios or visions if they do occur (Ratcliffe 2002). The feasibility of taking actions and making policies is also assessed (Keenan & Koi-Ova 2003).

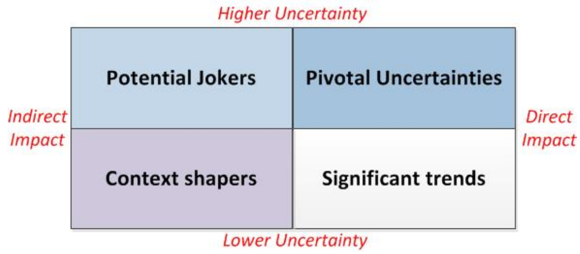

Figure 7. Weak signals analysis. Figure adapted from (Ratcliffe 2002) from figure 2, p. 28

According (Mendonça et al. 2003) weak signal analysis focus on events that their likelihood to happen is very low, but if they do happen the uncertainty on their impact and on the trends that they can provoke is very high. Coffman (1997) cited by (Mendonça et al. 2003) has defined weak signals as indicators of wild cards.

Usually, this process starts with horizon scanning and stakeholders workshops in order to collect information and make a list of strategic issues specific to the problem at hand such as trends (social, political, economic, technical) and events that may have a discontinuous impact on the problem at hand (Collection of weak signals as open ended questions).Then, both the likelihood that the issue will occur in the future and the impact of issue on the problem at hand are assessed. The results are ranked according to their importance and deviation (see Figure 8). The high relevance/ low deviation quadrant in the schema below, signifies the current dominant beliefs of the issues that are viewed as more relevant (strong signals) by the majority of experts. The low relevance/high deviation quadrant lists issues that the participants have strong difference in opinions as to what is considered to be of low relevance (weak signals). The high deviation/high relevance quadrants are potential issues (Leonie Project 2005).

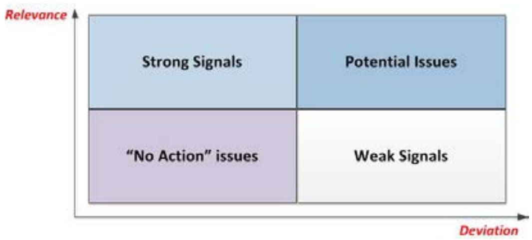

Figure 8: weak signals analysis. Figure adapted from (Leonie 2006) from figure 13, p. 40

In 'Dynamic Roadmapping', factors of change are analysed in order to identify key uncertainties, trends, tensions, and assess their impact. Based on this analysis, and a set of foreseeable context scenarios are created, as well as alternative strategies per scenario for managing the impact of these factors on the visions (desired changes) and the co-innovation roadmaps. Such analysis also provides some observable specific indicators, which are monitored on a continuous basis through an observatory function. Strong signals are trends that will be played out in all scenarios. Signals characterised with high uncertainty, but also with having high impact if they happen, are grouped and used in order to create the two polarity axes (as distinct and as inclusive as possible) of the scenario matrix.

There are several reasons why weak signals are not acted upon. According to Ansoff (Ansoff 1975) the researcher who first introduced the term, several filters prevents us from observing the weak signals in a way that could change our course of action (see Figure 9). *A surveillance filter* includes methodology and analysis techniques similar to horizon scanning and information acquisition. When the signal is passing the surveillance filter, it is captured, and will go through *a mentality filter*, which is described as a close equivalent of mental model. The last filter is the *power filter*. It signifies the prevailed mental models in an organization. It gets activated, when a weak signal challenges the power structure of the organization. Managers, whose positions and importance are threatening by the disruptive change that the signal signifies, try to either neglect it or to hide, delay or ignore its significance (Ilmola & Kuusi 2006). These managers are likely to be middle managers or top managers (but not the founders) of large, well –established firms, who will stand for the tradition of the organization and for incremental improvements of the current business (Yu & Hang 2010).

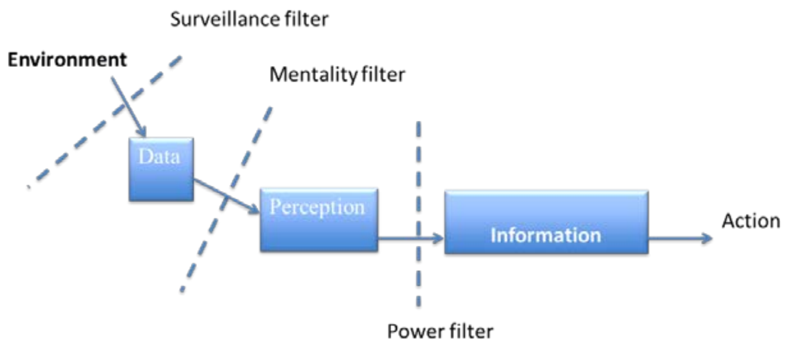

Figure 9. Ansoff's weak signals filters. Figure adapted from (Ilmola & Kuusi 2006) from figure 1, p.912

2.1.7 Other Future Methods based on Systemic Approaches: Future Search

Future Search (Weisbord & Janoff 2000) and its Search Conference (Emery & Purser 1996) are intensive workshop based management approaches aiming to help social systems to become adaptive. They are based on 'Systems Thinking' methodologies and they have been developed to meet the needs of the Action Research approach (O'Brien 2001). Future Search provides the framework of the approach, while Search Conference is the actual tool in a form of a workshop that implements this method. These are particularly effective when common ground needs to be established across all the key stakeholders, with conflicting interests and viewpoints, but who none-the-less need to work together to move forward on the issues in the system those they are all involved in. The search conference format has seen widely used Future Search Conference are the result of developments over several decades and have been successfully used worldwide on hundreds of occasions. It requires that all the key stakeholders meet in a retreat, establish trust, leave their differences aside, and formulate a shared future that addresses all their needs and concerns and make action plans for carrying it forward. This is a complex undertaking and takes time. The Future Search format requires all stakeholders commit to work together for three consecutive days up to sometimes a week to achieve this goal. This is because no amount of separate bi-lateral meetings can achieve comparable outcomes of trust, shared vision, and commitment and follow through. The format also is ideally framed around 64 participants in 8 stakeholder groups, but typically there is between 60 and 70 participants. An extensive effort is required to prepare the Search Conference. This is mainly due to obtain the commitment of all key stakeholders to participate, making sure they fully understand what it is addressing and what outcome is being sought. Contributions in all sessions of Future Search are made by the members themselves, while staff is focusing in facilitating activities only. The group explore its own organisational settings against a wider environment and then tries to develop common visions as desired futures. After they agree on a common future, they are planning action steps for its implementation.

In order to formulate the stakeholders group, they use the acronym: ARE-IN (Weisbord & Janoff 2010), which represents those people with the:

- **A**uthority to act: the decision makers in an organisation or community who can authorise or prevent certain critical actions.
- **R**esources needed to implement plans: those with time and/or money needed to implement the plan. These will be varied.
- **E**xpertise in the issues being considered: often professionals, researchers or developers with specific knowledge and skills.
- **I**nformation about the topic that no others have: those who have first-hand knowledge about and/or experience of the area in focus.
- **N**eed that is being addressed: those who are currently disadvantaged or suffering in the current situation, or who are the clients or customers if the area is a business domain, or inhabitants if it is a locality or region that is the focus.

In 'Dynamic Roadmapping' framework *a modified version of the Search Conference was adopted* in order to identify a shared future and shared visions/desired future scenarios. *The ARE-IN principles* of the Future Search were also adopted in order to create the co-innovation group (as part of the top-down approach). Similarly to Future Search, in meso level 'Dynamic Roadmapping', it is important to bring together all necessary stakeholders in order to design, agree and implement their roadmaps. The Future search approach was used in order to build trust and commitment to joint action among the stakeholders.

2.2 Innovation models

In order to develop effective technology management and roadmapping methodologies, it is very important to understand the nature of the different technology innovations and how they differ from each other. The type of innovation will determine the choice of foresight, forecasting and roadmapping methods that must be applied for the successful development and adoption of the innovation.

The *'punctuated equilibrium model'* is the most common model for describing technological innovations (Gersick 1991). Under this model, a radical new technology starts the technological evolution. This technology destroys the previous competence models of the firms in the industry. This is marks an uncertain period, which is characterised by intense competition among firms, as to who will establish the next dominant technology/process/product design. Firms, according to Arthur's hypothesis of increasing returns (Arthur 1987), will benefit from producing the dominant design therefore, they are highly motivated to predict and choose to align with and support the right emergent design. Once a design has established, the industry's firms, suppliers and customers are locked-in *('bandwagon' effect).* A period of incremental innovations is followed, where firms are trying to improve the existing design and provide better quality of product and services at lower costs. If a new discontinuous technological innovation occurs, the previous technology cycle is moving to a new trajectory. These initial trajectories are usually modelled in an S-Curve. Firms who have adopted the technology can innovate at various points along the S-Curves (Petrick & Echols 2004).

(Petrick & Echols 2004) claim that a company has three choice when it comes to innovation*:* a) develop a new component to be used in an existing system – incremental minor innovations along the S-curve b) develop a new system using existing components (major innovation driven by market pull or technology push) and c) develop a new system with new components (radical or disruptive innovations, new technology trajectories, competence destroying). The firms must consider the impact of innovations in terms of whether they are replacing existing technology trajectories (discontinuous or disruptive), component platforms and architectures or complementing existing ones (incremental symbiosis) .

In order to successfully introduce and manage technological innovations and choose an innovation strategy, which will speed up their adoption and scale, it is important to understand the nature of the different innovation models (e.g. incremental, disruptive, radical, systemic) and the dynamics of the technology evolution in causing systemic changes in the respective technological, economic, social and business frameworks. In addition, it is more likely for the start-up firms to develop radical or disruptive innovations than the incumbents firms. In some cases, to develop these types of innovations, it will require an entire network of firms and other stakeholders, to openly collaborate with each other.

2.2.1 Six generations of innovation models

Understanding innovation as process, from its generation to its commercialization and scale, is very important because it makes it easier to manage it (Kamtsiou & Nascimbeni 2013). This understanding has evolved in the past decades and resulted in a classification of six main generations of innovation process models: technology push, Market pull, coupling model, interactive model, networked model, and open innovation model (Preez & Louw 2008).

Early models interpreted innovation as a linear sequence of activities, whereas later models try to build more complexity and interaction into the innovation models (Tidd 2006). (Preez & Louw 2008) summarised the key features of the different innovation models generated over the last decades (Rothwell 1992), (Tidd et al. 2005), see Table 2. The first two models are limited to innovations that produce standalone products. They are linear models, starting from an idea, moving to pilot and to commercialisation. The third and fourth models take into account the need for feedback loops between research and marketing, as well as among other departments in the company, in order to produce the innovations. These models link technological advantages to market drivers and the capabilities of the firm. But, like the two prior models, they are still not addressing the complex transactional and contextual environments of the innovations. Therefore, such models do not address the implementation and adoption of the innovations. The last two models, "networked" and "open" are better fitted to address systemic innovations. This is due to the non-linear nature of such innovations, which requires the involvement of many players and the need for their coordinated collaboration. *One key challenge* for managing systemic innovations is the sense making of complex systems and the uncertain factors and drivers affecting these systems, whether technical, social, political or economic. In that sense, foresight methods could be used in order to make sense of the drivers, the associated uncertainties, and also to provide an increased understanding of the possible threats and opportunities, associated with the innovation's adoption.

Model	Generation	Characteristic
Technology push	First	Innovation process is linear from a research idea to pilot to implementation, emphasising R&D and science. Technology push driven.
Market pull	Second	Innovation process is linear, starting from market drivers with emphasis on marketing. In this model, the market is the source of new ideas for R&D. Needs pull driven.
Coupling model	Third	Interaction between different elements and feedback loops between them are becoming critical in innovation process. Emphasis on integrating R&D and marketing. Both technology push and market pull.
Interactive model	Fourth	Combinations of push and pull models. Integration across the firm's organizational functions involving the entire value chain of the firm. Emphasis on external linkages and alliances with suppliers and customers.
Network model	Fifth	Emphasis on the influence of the external environment. Closed innovation networks involving external and internal stakeholders. Generation of ideas is still restricted within the company. Emphasis on different intelligences, external linkages, systems integration and extensive networking.
Open innovation	Sixth	Open innovation networks. Generation of ideas can happen both internally, within the firm, and externally from networks. A combination of internal and external paths to market in order to advance the development of new technologies.

Table 2*: Evolution of innovation models compiled from* (Preez & Louw 2008) *from table 1., p.2.*

2.2.2 Networked versus open innovations

In 'open innovation', firms use both internal and external ideas within and across their industry boarders, in order to develop radical new products and services. Moreover, the firms rely on internal and external resources and capabilities (e.g. spin offs, universities, research centres, co-innovators, suppliers, adopters, intermediaries, etc. for producing the innovations). In contrast, in closed innovation models, firms "generate their own ideas, develop them, market them, distribute them, service them, finance them and support them on their own" (Chesbrough et al. 2006). Open innovation models, compared to networked innovation models, provide access to more integrated ideas from many sources, while minimize the innovation risks, especially in turbulent times of high uncertainty. In addition, extended open networks provide firms better chances to learn about changes in their external environments and capture early warning signals more effectively (Schoemaker et al. 2013). Therefore, firms with extended open networks (suppliers, customers, researchers, technologists, co-innovating firms, etc.) are less likely to miss signals that are coming from the periphery and outside their immediate business. Open innovations are usually useful for developing and adopting systemic innovations (whether incremental, radical) within an existing industry, which will not threaten established players, but nevertheless require their collaboration for the innovations' adoption. On the other hand, networked innovations are better suited models than open innovation models, for creating competitive technological advantages for a single firm or for few firms in a closed network. These advantages (e.g. technological patents) will allow for the development of a portfolio of innovations, while ensuring first movers advantage in the market.

In case of TEL, the open innovation model seems to be the best fitted model, since TEL innovations have a systemic nature (Nascimbeni & Kamtsiou 2014),(Bocconi et al. 2012), (Kamtsiou & Nascimbeni 2013), (Meiszner et al. 2014), (Kamtsiou, Olivier, et al. 2013), which implies the simultaneous collaboration of very different actors in producing products and services that will radically transform the sectors of education, professional learning and informal learning in social networks. This complies also with the idea that a single organization cannot innovate alone, but it must engage with different kind of actors to get new ideas and resources and to remain competitive. Innovation in TEL necessitates the need to make sense and analyse not only the innovation processes, but also (and mainly) the significance of interconnection among the actors involved in the processes of innovation. In other words, the whole ecosystem of TEL stakeholders needs to be considered, when dealing with TEL innovations.

2.2.3 Systemic versus incremental innovations

Incremental innovations are concerned with minor changes (improvements) in products, process or services. Systemic innovations require that several firms need to change their processes in order for the innovations to be developed and or adopted, thus they are adopted more slowly than incremental innovations. (Taylor & Levitt 2004) argue that "Systemic innovations requiring multiple companies to change in a coordinated fashion including recent advances in supply chain management, increasing use of enterprise resource planning, and the prefabrication of component systems (Taylor & Levitt 2004)." Even in the case that the benefits of systemic innovations are evident; their adoption could still be very limited because of the reluctance or inability of some of the involved stakeholders to change their processes and or practices. Systemic innovation, according to Geels and Schot is driven by a multi-dimensional and often cross-impacting factors stemming from changes, in socio-technical environments. These innovations are characterised by complex systemic interactions related to their production, adoption, scale and use (Geels 2004). Like disruptive innovations, they are usually initially introduced and adopted by Niche markets.

2.2.4 Disruptive innovations versus incremental innovations

Disruptive innovation is a powerful means to expand, develop new markets and provide new functionality, which unlike incremental innovations, will disrupt market linkages and/or replace market leaders (Yu & Hang 2010) (Adner 2002), (Christensen 1997). In their early stage, disruptive innovations can only server niche segments, which value non-standard performance attributes. According to Christensen "disruptive innovation happens in a process. Disruptive technologies are technologies that provide different values from mainstream technologies and *are initially inferior* to mainstream technologies along to the dimensions of performance that are most important to mainstream customers " (Yu & Hang 2010). Christensen identified the issue of non-consumption, arguing that disruptive innovations offer new added value at low prices to customers who are not currently served by the traditional offerings. (Adner 2002) argued that customers switch from traditional offerings to disruptive innovations, because performance improvements in the main dimensions of the traditional offerings are considered of marginal importance by some customers. Govindarajan and Kopalle extended disruptive innovations theory by adding the idea that disruptive innovations can be both of initial inferior quality and of higher price compared to mainstream offerings. They gave the example of cellular phones, which when first introduced, they had a lot more limited reception range compared to the fixed phones (thus inferior quality) and they were a lot more expensive. They were adopted by a niche market of corporate executives' types of customers who highly valued the portability of the phones. Nevertheless, all theories recognised that disruptive innovations always started with inferior quality offerings as compared to the traditional offerings. Innovations that offered radical improvements in performance at either low or high prices are *classified as radical or distractive innovations* (Govindarajan & Kopalle 2006). Figure 10 maps the two types of disruptive innovations characterised as a) initially lower performance offerings at low costs as defined by Christensen, or b) initially low performance offerings at high costs as added by Govindarajan and Kopalle and their differentiation from radical innovations, which are referring to higher performance offerings at low costs.

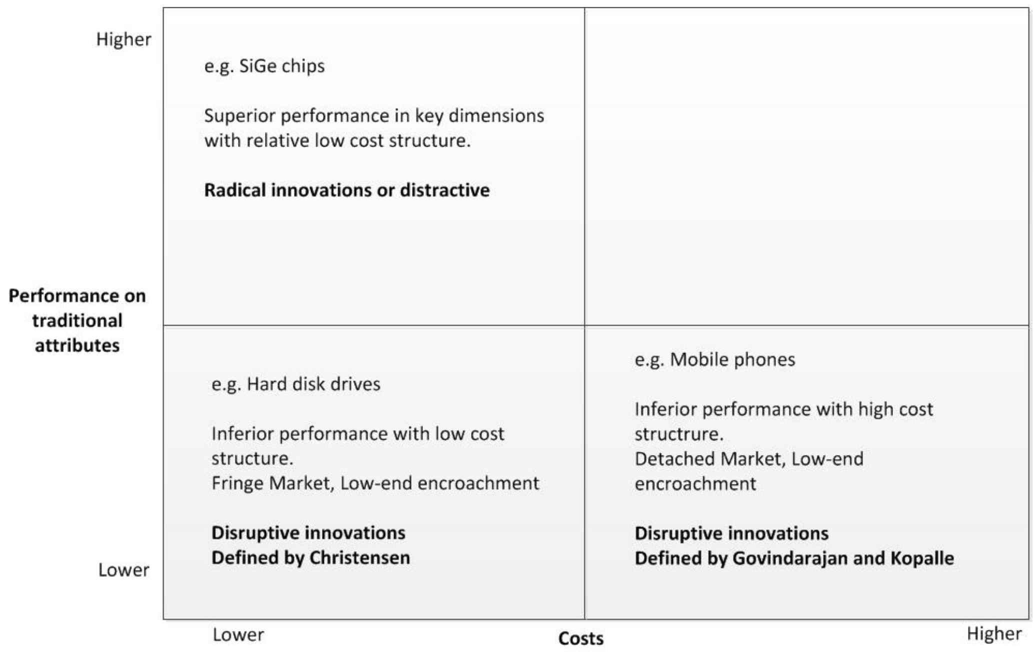

Figure 10. Disruptive and radical innovation models. Figure adapted from (Yu & Hang 2010) from *Figure 3, p. 438*

Open innovation models may be applied to manage disruptive innovations, when there is a lack of complimentary resources and skills that are needed in order to create and market these innovations (Paap & Katz 2004). Disruptive innovations are faced with resistance from the incumbent firms and especially from middle managers. Locked in relationships with suppliers, and other intermediaries might also refrain companies from adopting disruptive innovations (Yu & Hang 2010).

In many cases, in order for disruptive innovations to be implemented, several other innovations and competences must be developed by other co-innovators (Meyers et al. 2002). Therefore, regional clusters of co-innovators can help manage the adoption of disruptive innovations. In that sense, disruptive innovations resemble systemic innovations, although usually systemic innovations do not aim to replace existing market leaders, but rather to provide radical improvements on existing offerings. In 'Dynamic Roadmapping' model though, systemic innovations could be either sustained/radical or disruptive types.

2.2.5 Classification of TEL innovations according to JRC report

The JRC report (Kampylis et al. 2012) *ICT enabled innovation for learning* "refers to the profoundly new ways of using and creating information and knowledge made possible by the use of ICT (as opposed to using ICT for sustaining or replicating traditional practices). It deals with both formal and informal learning, covering traditional education settings (schools and higher education) and adult education. Last, but not least, this ICT potential for innovation must be realised and accompanied by the necessary pedagogical and institutional change." According to IPTS, "the paradigm underpinning ICT-enabled innovation for learning entails a holistic transformational shift towards connecting learning organisations and processes (i.e. connecting the realities of learners' lives and their experience of school). It applies the four principles of social innovation, where innovation is conceived as open, collaborative, free and characterised as "with" those involved (and not innovation "to" or "for")".

IPTS has proposed a classification framework for categorise TEL innovations which was developed during the Scale CCR Study (SCALE 2009). This framework has a spider diagram format as it is depicted in Figure 11. Although such framework is extremely useful for categorisation of TEL innovations, it is observed that the "systemic" innovation type is missing from the schema, although according to JRC they are the main type of TEL innovations.

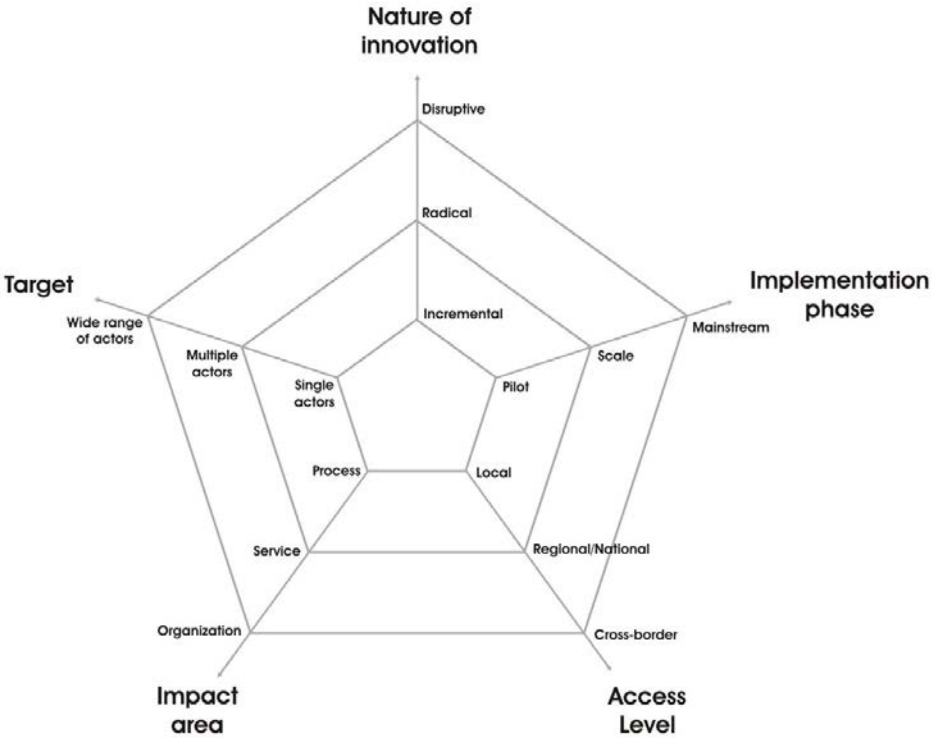

Figure 11.Categorising ICT enabled innovation source (IPTS-JRC 2012)

2.2.6 Technological framework of innovations according to their nature

Figure 12 provides categorization of technological innovation according to *the nature of the innovation* i.e., disruptive, linear/incremental, systemic. Systemic innovations can be both emergent/sustained, radical and/or disruptive (Kamtsiou 2013), (Aceto et al. 2014), (Kamtsiou & Nascimbeni 2013), (Kamtsiou 2014).

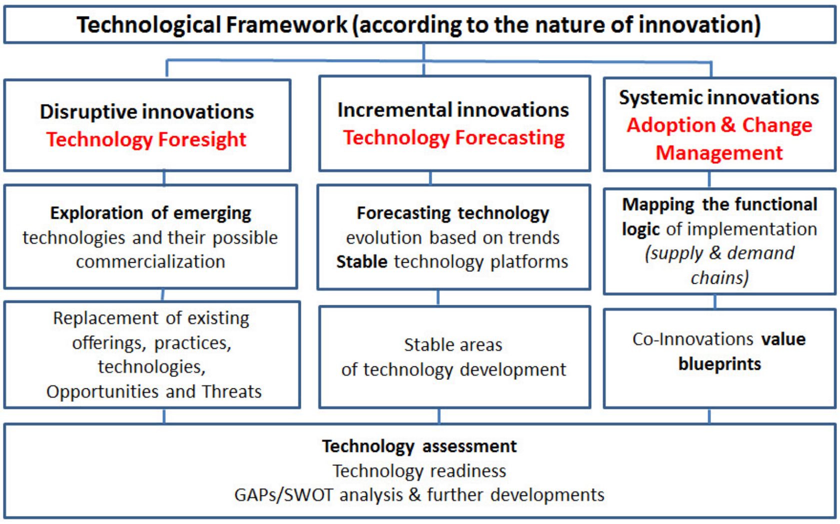

Figure 12: categorisations of TEL innovation: author's own compilation adopted by HoTEL (Nascimbeni & Kamtsiou 2014) *and CRE-AM projects* (Kamtsiou 2014).

The identification of emerging technologies and their possible commercialization (Technology foresight), as well as their possible evolution (Technology forecasting from existing trends), are both needed in order to identify risks, opportunities and threats related to such developments and the impacts of these technologies at some time in the future (Technology assessment) (Porter et al. 2004) (Strauss & Radnor 2004). In addition, a plan for adoption of the foreseen innovations must be developed, which would include all the relevant actors involved in the innovations functional logic for implementation. Depending on the nature of innovation incremental, disruptive or systemic, different approaches and methods are used in order to assess possible technology gaps. Each of these "technology intelligences" (including market and economic intelligences related to adoption of these innovations) support innovators in order to assess their innovations and achieve their successful implementation under a number of plausible technical, social as well as learning and business contexts.

Incremental innovations: Technology forecasting methods

In case of incremental innovations (or sustained innovations), usually technology forecasting methods are used in order to assess technology readiness and ability to add value in existing TEL solutions. Related activities are:

- identify critical requirements and "products" to be developed (added value)
- identify major technology areas and technology drivers
- identify technology alternatives and their possible evolution based on strong trends, historical data, hype curves and technology life cycles or S-Curves
- assess technology readiness.

S-curves are growth curves widely used for Technology Forecasting. The growth curves have an “S-shaped” form, similar to life cycle curves over a period of years. “An S-curve represents a technical performance as a function of time or research effort and its shape is influenced by market demand, scientific knowledge and level of investment or innovation” (Phaal et al. 2004b). In the beginning of the S-curves, still at incremental growth stage, we expect to be able to make good predictions on the technology evolution. In the top of the S-Curves the picture is very different. Similar to life-cycle analysis, as technology matures further improvements are not possible or customers are being overshoot with quality. At this point, substitute or new emerging technologies are replacing the mature technologies. This is a turbulent time until a new dominant design emerges (see Figure 13). Since, by definition S-Curves of different technologies are not linked, technical discontinuity is a given and managing the transition to the new technologies is difficult depending on the nature of innovation (e.g. incremental, disruptive, systemic, convergence at the interface of more than one technologies, etc.). Similarly, although S-Curves are very useful to assess technology evolution, to plan strategies for incremental innovations, and to compare different technologies, *they are not effective for predicting the impact of disruptive technologies*, since they usually introduce a new type of performance parameter, thus they cannot be measured against the existing technologies. For example digital cameras introduced the new function of access to pictures immediately without the need of chemical processing (Bower & Christensen 1995), (Carlsen et al. 2010). *S-curves cannot also be used for systemic technologies*, since their interaction with other technologies and their impact to the whole system need to be considered (Petrick & Echols 2004), (Christensen 1997).

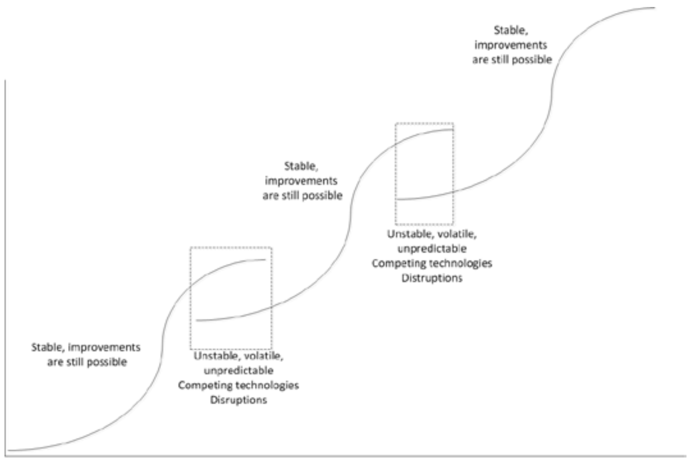

Figure 13. Evolution of S-curves (current and emerging). Figure edited and adapted from (Linstone 2004) from Figure 1, p. 189

Disruptive innovations: Technology foresight methods

In case of disruptive innovations, we need to understand the possible innovation opportunities stemming from the emerging technologies and any threats or weaknesses that might influence their adoption. Identification of possible trends and signals that might lead to disruptive innovations is also very important. Usually, Open innovation models may be applied to manage disruptive innovations, because of lack of complimentary resources and skills to create and market these innovations. Regional clusters of co-innovators can also help manage the adoption of disruptive innovations (Paap & Katz 2004) .

Questions that the innovators need to answer are for example:

- What will be the innovation's potential for commercialization, in terms of desired applications, products or services?
- Which products, technologies, practices or even markets will be disrupting and or replacing?
- What will be the resistance from the current players in the market?
- What it means in terms of the adoption of the new technologies?
- Who else needs to come in an agreement in order for the innovations to be created and adopted?

The analysis of the S-curves in technology forecasting methods also provides a first indication of when a new technology will be most likely to appear as a replacement of a mature one. S-Curves could also be used to understand both, if traditional attributes show of an overshoot to current customers, and/or if lower costs emerging products or services are emphasise secondary attributes (SCHMIDT 2004).

Sometimes, disruptive innovations are used in a sense of radical innovations, which provide superior performance or services compared to current offerings of the market leaders. Figure 14 shows a comparison of traditional technologies against the S-curves of emerging technologies. This comparison provide insights whether there is a real superior performance of the emergent technology in comparison with the traditional technology, which would motivate the decision makers (suppliers, producers) in the industry to invest in it and replace the previous one (Tierney et al. 2013).

Furthermore, *foresight methods* are usually used in order to identify and understand the uncertainties and changes in the socio technical landscapes (including their PESTLE drivers). The development of plausible scenarios is often used as a method in order to analyse drivers for change and their signals, as well as other competing technologies (including the possible integration of several technologies) and their disruptions. In case of innovations developed at the integration of several technologies, these convergent technologies are usually grouped and considered as one new technology to be assessed. An alternative method to scenarios (plausible futures) *comes from systems thinking approach*, where the causal relationships between concepts are analysed.

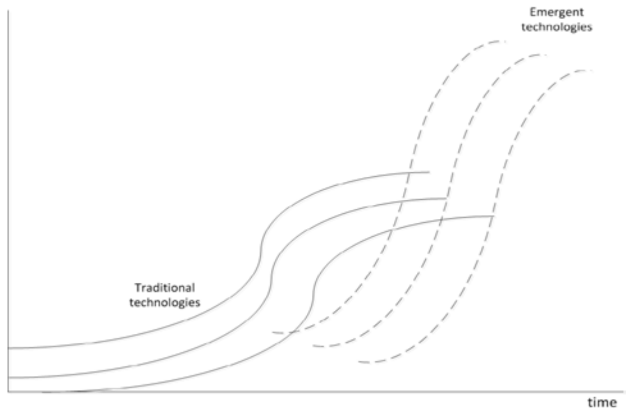

Figure 14: Traditional technologies S-curves, versus emergent technologies. Figure adapted from (Tierney et al. 2013) from figure 2, p.198

TEL innovations are difficult to be classified as disruptive with the possible exception of Higher Education and the emerging MOOCs model. In this case, students who do not have the time or cannot afford traditional Higher Education are provided with a strong alternative of highly targeted, low cost, time flexible education via MOOCs programmes. This is also true for some students who have been over-served with high quality education currently offered by Higher Education Institutions. For example, instead of full degrees they could be offered online education of a very specialised industry or specific competencies related courses or in some cases, students of Higher Education might feel overshooting by very expensive campus facilities and services. In case of schools, it is more likely to see radical and systemic, rather than disruptive innovations, which would not aim to replace schools as institutions, but to enhance significantly the learning experience. These innovations could introduce radical changes in the way schools are governed, curricula are created and they could change teaching practices and pedagogies. Therefore, it could be considered disruptive for Ministries of Education, Teachers, and Schools administrators, but since the offerings would be of radically higher quality compared to the current educational offerings, such innovations could not be characterised as disruptive. In corporate education, we could foresee a possible disruption of current TEL providers' markets. This is more likely to happen by technological innovations outside the TEL industry or on the boarders of TEL. Such innovations could include intelligent tutors, AI, Data analytics, gesture interfaces, Internet of things, mobile technologies and social media.

2.2.7 Systemic Adoption and change management: TEL innovations example

The field of Technology Enhanced Learning (TEL) is considered to be a diverse and multi-level domain, involving many types of players, working in different cultures and operational contexts, under varying jurisdictions, with differing and sometimes opposite approaches to pedagogy and the task of education. In complex domains, such as TEL for example, innovation is often systemic, involving several converging and or competing technologies, complex interactions by many players, who have to collaborate in order to develop holistic solutions, integrated in pedagogical and educational models. Multiple root technologies, such as content delivery and assessment need to be integrated with other technologies that are found outside TEL, such as those related to data analytics, Intelligent Agents, mobile technologies and devices, internet of things, etc. These kind of technological innovations which are produced on the interface of several technologies are in turn giving birth to new pedagogical innovations, and new learning and educational practices, such as seamless learning, microlearning, Rhizomatic learning, etc. Applications like MOOCs and Personal Learning Environments (PLEs) are disruptive to the way higher education is organised and delivered in universities. Hence, these types of systemic innovation have *"a nature of integrality"* (Kaivo-oja 2011) and at the same time a nature of *multi-diversity*, since the applications envisioned usually require for different development pathways per involved technology. Looking more at the adoption of TEL in general and 'products' in particular, it is also complex, with many technical, pedagogical and organisational interdependencies. Different providers of systems, content and services are often mutually dependent and a degree of coherence between them is necessary to transfer TEL innovations to the mainstream. This is especially true for TEL domain, where technology is not the prenominal factor of the innovation, but is more of an enabler of innovative learning pedagogies and practices. So, rather than looking at independent 'products', the focus is instead on TEL 'opportunities' and 'value propositions'.

Consider for example how innovations or "value propositions" from software designers and platform developers influence and impact the individual contexts of teachers (teaching practices at schools, training needed to adopt the new systems, their professional development) or those contexts of schools administrators and IT managers, were they need to make informed decisions on access, affordability, quality, and adoptability to existing organizational processes, or in the context of a ministry of education, who may have a say in how the innovation fits with the school curricula, place and time of adoption.

Let's consider for example the technology providers of content repositories. They are also depending on teachers in order to create and share content with other teachers and to integrate it into their lessons plans, learning designs, curricula and classes. Moreover, these new tasks require allocation of extra time in the teachers work schedules, thus call for replacement of other teachers' activities and for changes in the rules of how the teachers will be evaluated, promoted, and advance their carriers. They also might require the development of new learning designs and pedagogical models, as well the approval of the school's administration and depending on the national education system the approval of the ministry of education. Therefore, many other types of stakeholders have to come to agreement about what is wanted and how it should be provided. Government agencies, from local, through regional to national, as well as school decision makers, from heads to the teachers involved, also need to come to some level of agreement for an innovation to be mainstreamed. When organizations are looking to introduce and manage TEL innovations, they need to take into account the whole eco-system in which they are operating. The focus is *on desirable systemic change* by which it means changes in business (and learning organizations), learning processes and practices, as well as technological (software, and tools and infrastructure) and social (e.g. role of learning in developing European citizens, their employability, and personal fulfilment). At the same time TEL innovations can also be regional, national and at European levels.

For systemic innovations to be successful the “functional logic of the whole *production, delivery and supply chains* (suppliers, manufactures, distributors, value-added resellers, installers and consumers) may change because of the new innovations” (Kaivo-oja 2011). In case of TEL, educators, software developers, brokers, policy makers may also have to be aligned, co-innovate and make changes for the successful adoption of TEL innovations.

According to (Kaivo-oja 2011), most common types of incremental innovations are (1) technological innovation, (2) business innovation and (3) social innovation. In systemic innovations, these 3 types are systemically interconnected, thus systemic changes in one of these three innovation types can introduce changes or innovations in the other two innovation types as well (Kaivo-oja 2011). It also means that innovation systems will be influenced by interlinked social, political, economic factors and forces (see Figure 15).

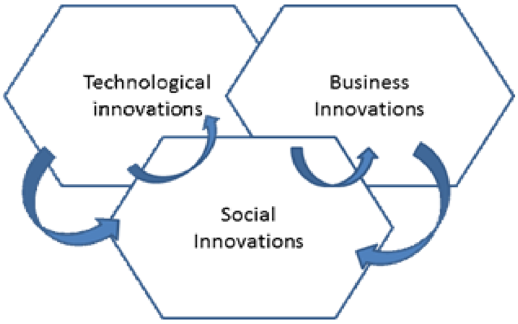

Figure 15. Synergy field of systemic innovations. Figure adapted from (Kaivo-oja 2011) from figure 1.a, p. 7

For systemic innovations to be successful, the synergies among these 3 types of innovations must be understood and analysed. First, we need to decide which element drives the systemic innovation (key innovation element) and then organize the other elements inside its strategic framework logic. Figure 16 shows an example in which the (1) technological aspect is the key element the innovation. Then the other 2 elements are the subsystems of the larger systemic innovation (Kaivo-oja 2011).

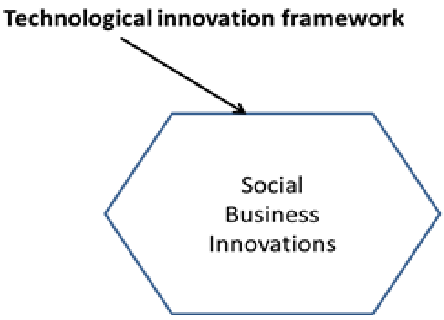

Figure 16. Technological framework for a systemic innovation. Adapted from (Kaivo-oja 2011) from figure 1.b, p.7

(Könnölä 2007) uses a similar structure to classify systemic innovations (see Figure 17). He identified four elements i.e. *technological change, industrial change, social change and* *policy change*. Industrial change is defined as ‘Standards, Interoperability, value chains and networks, organisational hierarchies’. He also adds ‘Policy changes’ and defines them as ‘Regulations, economic instruments, governance, agreements, communication, and coordination’.

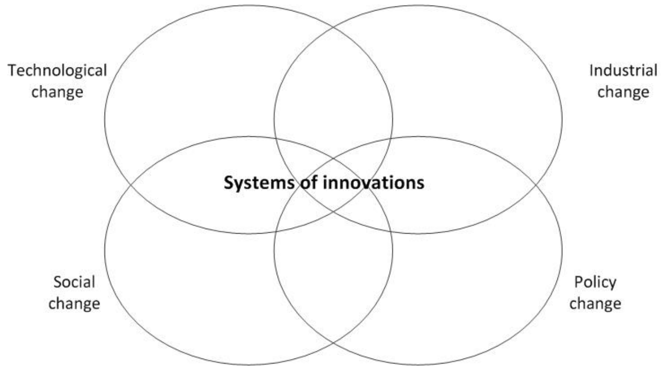

Figure 17. Systems innovations and their dynamic linkages. Figure adopted from (Könnölä 2007) from figure 3.2, p. 9

In order to understand the technological framework of TEL innovations, these models are merged and adopted as showing in Figure 18. An additional innovation type ‘learning practice innovations’ is added to this model. In a more generic model, this new type could relate to ‘Industrial innovations’ in (Könnölä 2007) model, since it is related to domain innovations.

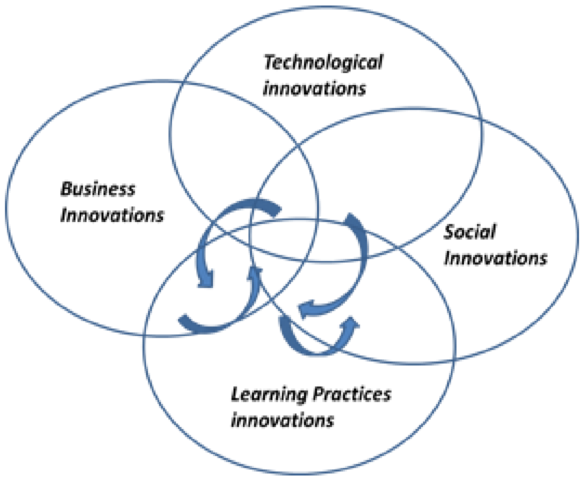

Figure 18. Synergy field of different forms of TEL innovations. Based on modified (Kaivo-oja 2011) and (Könnölä 2007)

Following the same logic, depending on the key innovation element (which drives the innovation); we need to understand the functional logic of its strategic innovation framework.

Figure 19 shows the logic of the technological innovation framework. In this example, the key element of the innovation is technological changes. It also outlines the types of possible questions that we need to ask in order to explore the possible systemic changes driven by technological changes in the other 3 areas (business, social, learning). This example is based on (Könnölä 2007)and (Kaivo-oja 2011) models and it is reflected on the experience from HoTEL and TEL-Map projects (Nascimbeni & Kamtsiou 2014).

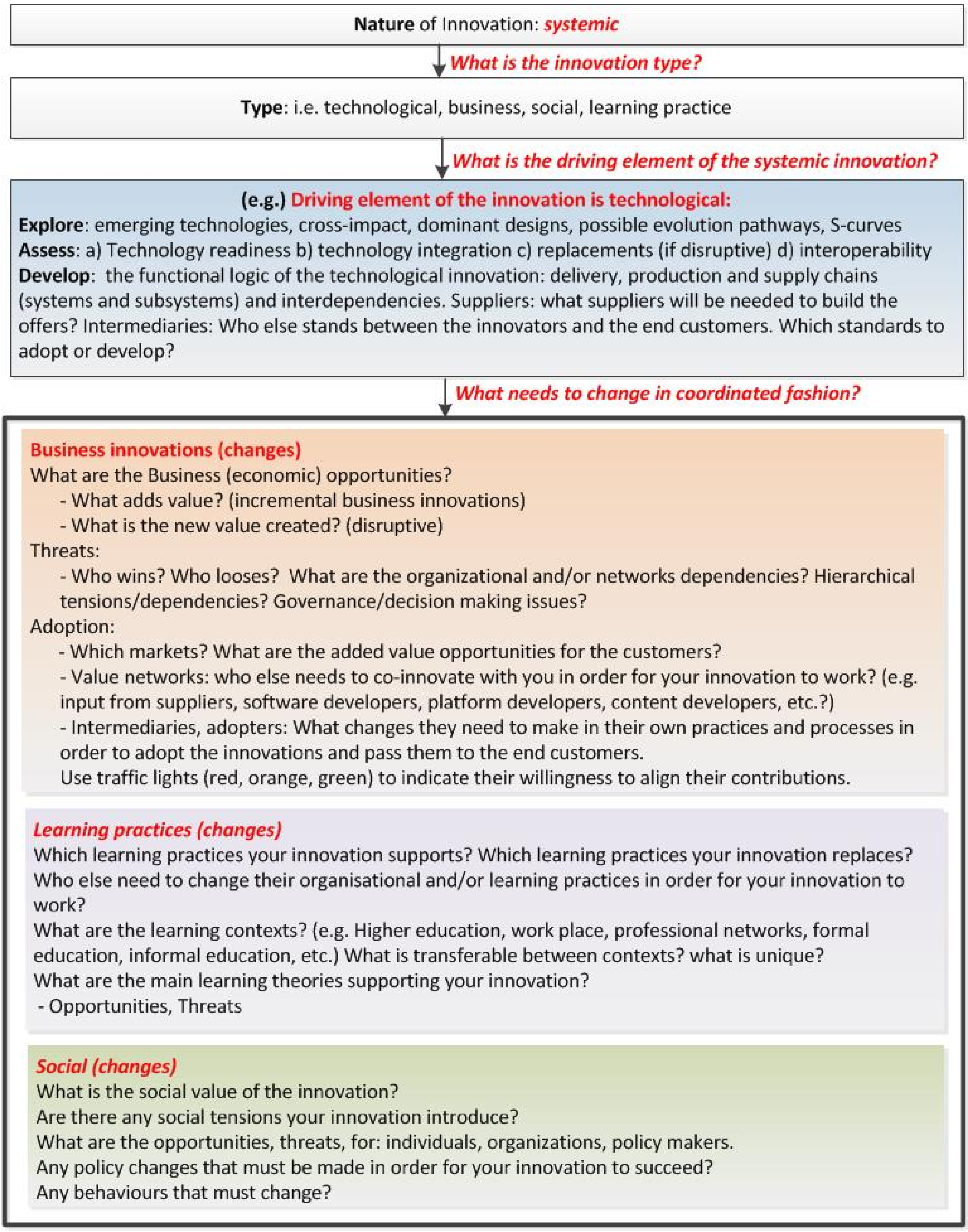

Figure 19.Technological innovation framework: TEL innovations. This framework was adopted by HoTEL (Nascimbeni & Kamtsiou 2014) and CRe-AM[1] (Kamtsiou 2014) pro*jects: source author's own compilation .*

Adoption problems in systemic innovations

[1] CRe-AM 'Creativity REsearch Adaptive roadMap' is an FP7 EU project, running from October 2013 to September 2015: http://www.cre-am.eu/

As analysed above, in the past, many originally very promising technologies have run into a "last mile" problem, essentially failing to convince either the actors involved in the supply-delivery innovation chains or the wide majority of users of their benefits. *Technology adoption* is about making technology available (*a delivery process*) and most importantly about people, their expectations, and what they imagine and then learn about what a technology can do (*a social process*). A practical example of technology adoption, integrated in 'Dynamic Roadmapping' as a change management model and successfully adopted by TEL-Map project, was based on Ron Adner's model published in his book, The Wide Lens. A new strategy for innovation, by (Adner 2012). Essentially Adner's points to the dependencies an innovator will often have on co-innovators as well as with the innovation value chains of suppliers and intermediaries. Adner's model is based on the assumption that individual technological innovations in order to be successfully commercialised, other complementary technologies must be developed prior and an agreement with suppliers of such technologies and other intermediaries must be made. He suggests mapping out these players and their interdependencies in a ***'value blueprint'*** (see Figure 20). The key questions are a) who else needs to be able to co-innovate with you before your value proposition reach your users? And b) who else needs to be able to adopt your value propositions before they reach the end users?

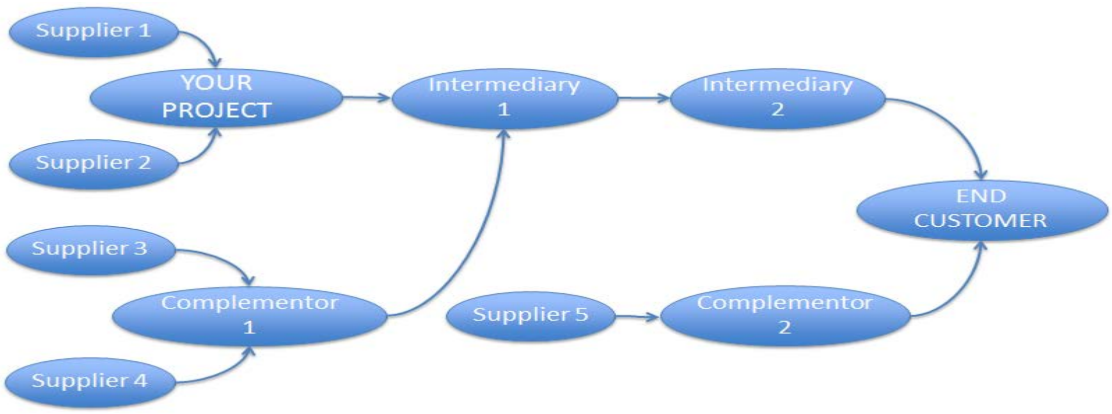

Figure 20. Value Blueprint. Figure adapted from (Adner 2012) from figure 4.1, p.87.

Adner provides an example from the publishers sector. The example is called the elusive E-reader, and uses the value print methodology in order to investigate why Amazon succeeded where Sony failed to develop the market for its e-readers. In 1990, Sony introduced its Data Discman Reader, but the venture failed due to very limited content available only on Sony-published CD. Limitations included: they were very expensive, too big, and tiring for the eyes. Then in 2000, online retailers sold 500.000 copies of Stephen King's novel Bag of Bones, a signal that motivated all major publishers to launch digital imprints. This led to increased sales for the publishing houses and in some cases revenues were doubled. Microsoft and Amazon started to compete for software to support the new e-books. Despite this success the current electronic reading devices were not selling. This was attributed to not user friendly hardware, difficult to find and to read the e-books. Sony launched a new e-reader in 2006 the PRS-500 Portable reader. Users could buy the e-reader at 350 dollars, 20% cheaper than the previous model, and could choose from approximately 10.000 titles available at Connect.com the online bookstore that Sony launched alongside the Reader. It was a two-step process to read the content. First the users had to download the content in a proprietary format to their PC and then transfer it from the PC to the reader.

Nevertheless, the reader failed again to successfully become adopted by the market. Main problem was its blueprints of adoption. The target customer was the book reader. Sony developed both the hardware and the standard for the e-reader. It partnered with excellent suppliers like E Ink and managed to develop a high quality product. At launch Sony saw all green lights across the project, supplier and intermediaries. They planned to bring on board many authors and publishers to Sony's own retail store. In reality, Publishers as adopters of the innovation saw only red lights (several economic, legal and quality concerns as well as copyrights and security issues).

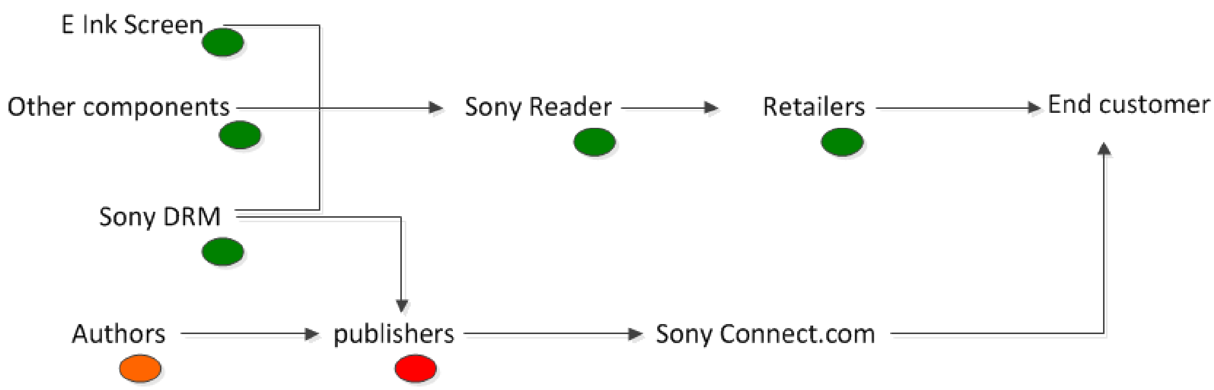

Figure 21. The Sony reader value print at launch. Figure adapted from (Adner 2012) from figure 4.31, p.94.

Figure 21 above shows the various dependencies that had to be managed and the willingness of the co-innovators and intermediaries to come along. These are simplified and represented in the map as green, yellow or red traffic lights against each player. It shows that Sony Reader Value Blueprint was an excellent technical product, but it was not a market success because the publishers, a key part of the whole innovation ecosystem, were not on board. Particular attention therefore needs to be paid to those players whose traffic lights are red, i.e. whose costs outweigh the benefits. If these key players' issues are not addressed, then there is little chance of the innovation succeeding.

Amazon in 2007 launched the Kindle and this innovation made e-books into mainstream. As a device, it was inferior to Sony's reader, heavier and with an inferior screen. But Kinder was a closed platform, which was reducing the risks associated with sharing the content with friends and others, or making it impossible to transfer content from other devices; it was a one stop shop providing a simple and cheap way to purchase and enjoy an e-book. It was positioned as a service and not a device. Figure 22 below shows the Kindle value blueprint.

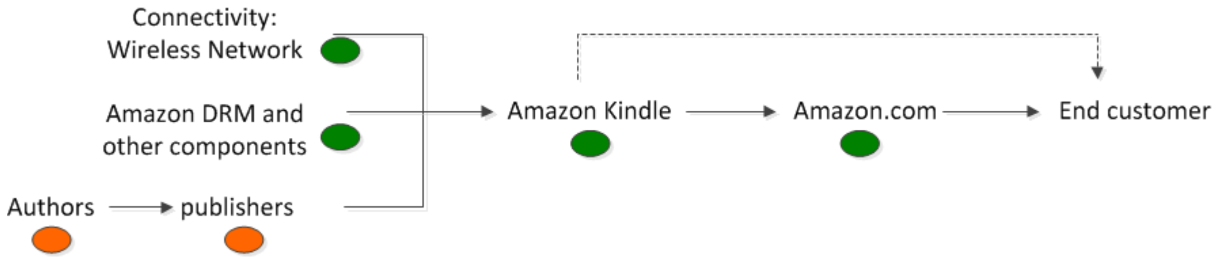

Figure 22. Amazon's Kindle value blueprint at Launch. Figure Adapted from (Adner 2012) from figure 4.4, p.96.

The key difference was the way they aligned the ecosystem to bring their value proposition to the end customer. This was a simplified proposition for everyone involved. No lights are red. In order to transform the orange light for publishers, it was critical to reduce their perception of risks and total costs. Amazon aside from solving the problems with piracy and copyrights, it also paid the publishers 50 % of the list price of the print version but then sold the e-book for 9.99 dollars. Moreover, its retail giant gave them a lot more power to approach publishers and authors with a good proposition.

Learning practices challenges

TEL innovations are more complex, since they need fit or to innovate/disrupt current learning practices and pedagogies.

In addition, the learning practices, which are supported or enabled by the TEL innovations, need to be identified and described. TEL innovators, need not only to be informed of the current and emerging learning practices supported by TEL, but also they need to understand the current analytical frameworks used by the educators, teachers, curricula developers, etc., and use them as checklists against the proposed innovations and the respective learning and pedagogical paradigms associated with these innovations. Such analysis of the related learning practices and the analytical pedagogical frameworks is intended to lead to improvements in the innovations' design or in the change-management of their adoption. In other cases, they may help identify the assumptions made of existing practices, which can be combined with the innovation to ensure its viability.

Social changes

Learning theory has been a contested scientific field for most of its history, with conflicting contributions from many scientific disciplines such as philosophy, psychology, biology, social science, neuroscience, practice and policy positions. In addition, the continuing and disruptive influence of technology on information, knowledge and practice in all sectors of society, draw innovators to the interactive potential that ICT brings to learning, but often overlook the challenges on the theoretical basis of education and learning which are stemming from such innovations (Nascimbeni & Kamtsiou 2014),(Aceto et al. 2014).

Formal education is also a high stakes, culturally & institutionally conservative activity which serves more than one societal purpose, including (Nascimbeni & Kamtsiou 2014),(Aceto et al. 2014):

- Each learner's personal development, fulfilment, and potential;
- child development and care;
- Preparation for citizenship, parenthood and retirement;
- provision of qualifications for profession;
- selection of jobs according to the anticipated social, economic, and market needs.

Even at the higher, informal and professional sectors of education, complexity of education is matched by complexity of learning which may include:

- skills, competencies, capabilities, development;
- knowledge acquisition and application of knowledge;
- improvement in strategic, analytic and creative capacities;
- establishment of attitudes and values.

Each of these societal purposes and learning areas demand different approaches and understandings for the learning pedagogics', but also for the TEL innovator and thus may develop at varying rates or found to be diverse in relation to context, location, economic conditions, technical possibilities, infrastructure, culture and national politics.

For example, in case of TEL innovations, if they span across more than one educational system (e.g. national education systems), or in more than one sectors, (e.g. Schools, higher education, professional development) or types (formal, informal), then their implementation may need to be adapted for each of these systems. Furthermore, as each educational system may evolve differently in response to wider political, economic and social pressures, the innovations may need to be continuously adapted to these changes as well.

As analysed above, different methods and steps need to be taken to analyse TEL innovations according to their nature (incremental, disruptive or systemic) and their types, technical (technology push), business (market pull), learning practices (bottom-up micro-innovations) and social (social needs pull).

Successful innovations need also to take into consideration: a) the integrated design process and the organizational architecture of the institution that adopts the innovation (e.g. to a company, a learning institution such as a University, a school or a professional organization; b) the design and implementation of the "product, services, practice"; and c) the design and implementation of new technologies (Preez & Louw 2008). A lot of very good ideas or even pilot products in TEL, whether they are coming from technology push, or practices (market pull) or research, they often fail to be successfully adopted and mainstreamed. A successful management of the innovation process (from idea to market) and a good understanding of the different innovation models are needed in order to guide this process from the stage of an idea to adoption and mainstreaming. It also calls for a coordinated efforts between research, pedagogical practice and technology development (e.g. commercial innovations from the industry players) and policy actions. The co-innovation group in ‘Dynamic Roadmapping’ model is responsible to integrate these different areas and to coordinate the developments (see also section 6.4).

2.2.8 Assessing Market adoption readiness

Rogers, as cited by (Taylor & Levitt 2004) classified the adopters of an innovation as early adopters, early majority, late majority, or Laggards. Another useful market adoption model for analysing technological innovations based on requirements for major changes of behaviour from users as adopters is developed by (Moor 1991). This approach is a good tool for assessing the market innovation readiness in disruptive innovations (see Figure 23). According to this model, the market adoption of a technological innovation resembles a bell curve that trucks customer adoption of new product or service extinction (Lee et al. 2011).

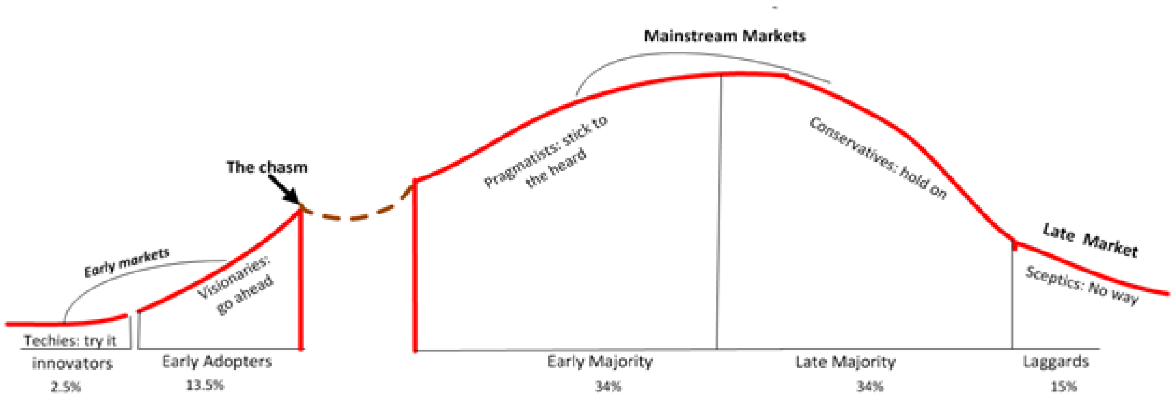

Figure 23. Technology adoption lifecycle (Moore’s Chasm) adapted from source: (Readwrite 2015)

Moore explained that although many technologies initially get pulled into the market by enthusiasts, later fail to scale and get wider adoption. It is therefore, critical for innovators to come up with strategies that will help them build a bridge across that gap. The characteristics of the innovation adopters in each category will assist the innovators in developing strategies to bridge the gap (Moor 1991). The complication in TEL and other types of systemic innovations is that *innovation adopters (end users) could be also suppliers of innovation*. For example, teachers adopt a new technological innovation in their learning practices and in turn innovate and produce new ways of organization, delivery and assessment of learning. Moore’s model appears to be primarily focused on the supply side, with the final end user or customer placed at the end of the chain, but not involved in the innovation process. In TEL, these types of ‘customers’ may include content providers, brokers, curriculum developers, competencies models, teachers, tutors, examination boards, assessment developers, etc., who may also add value to the technological innovation or their decisions may hinder its adoption. Therefore, a careful analysis of the types of adopters as well as their role in supporting the innovation must be made. In addition, it is difficult to think in terms of value chains, because of this none-linearity in innovations. It is therefore better to think of the entire ecosystem and its subsystems innovation value chains.

Moreover, sometimes those who decide to buy the innovations are not the same as those who have to use TEL, so the adoption process has two steps in two relevant categories: decision makers on one side, teachers and learners as direct users on the other side.

2.2.9 Assessing Technology readiness

Assessing Technology readiness

Whether we have to deal with incremental, disruptive innovations, or systemic innovations, a technology assessment in terms of technology readiness of the foreseen technologies to deliver the innovation opportunities (whether technological, business, practice or socially driven) needs to be performed. Most common methods include surveys in form of interviews with experts in both technologies (ICT) and business. TEL innovations are more and more happening on the interfaces of more than one technology rather than as a result of the development of one single technology. Technology Readiness usually measures individual technologies and not systems. Therefore, the operationability and the adoption of the whole system in its transactional, operational environments must be assessed as well. In case of systemic innovations, it is important to understand how the developed technology integrates in the bigger system and what disruptions it causes in the system innovation chains and its subsystems value-chains. For example, are the suppliers of the system influenced by the innovation (backward integration), or the customers (forward integration), or makers of other elements and subsystems (lateral integration).

2.3 Roadmapping as a process to develop and manage innovations

'Technology roadmapping' (TRM) is a process that helps to develop and implement innovation plans with emphasis on adapting to continuing changes in technology, market trends, new business opportunities, designs and processes. 'Roadmap' is the output artefact generated from the Roadmapping process (Gerdsri, Kongthon, et al. 2008), (Garcia & Bray 1997). The term 'roadmap' similarly with the term 'roadmapping process' is used in many different contexts and by different types of innovative communities and they can mean different things to different people (Kostoff & Schaller 2001). One of the most widely used definitions in the literature is provided by Robert Galvin (Motorola), who states that a *"roadmap is an extended look at the future of a chosen field of interest composed from the collective knowledge and imagination of the brightest drivers of the field"*.

Most researchers agree that Roadmapping is a *'process'* rather than a *'tool'* (Kappel 2001), (Garcia and Bray (1997), (Kerr et al. 2012). In most cases, this process is implemented via a number of workshops between experts and key stakeholders (Kerr et al. 2012). (Petrick & Echols 2004) define technology roadmapping as a 'tool' which assists firms to make conscious decisions about the future, minimise decision making risks and save time and resources.

A standard methodology does not exist

Technology roadmapping has become a widely used technique from the perspectives of individual companies, entire industries, research communities and governments. *However, a standard methodology of Technology Roadmapping does not exist*, and an examination of roadmaps that have been created indicate that there is considerable diversity among practitioners as to what constitutes a roadmap and how to assess the effectiveness and efficiency of the Roadmapping techniques employed (Koenig 1999) (Lee & Park 2005). As (Radnor 1998) pointed out "companies want to mechanize roadmapping, but much of it remains off the books. Roadmapping is political and involves negotiation and re-negotiation" (Radnor 1998). In the literature we find very few detailed descriptions of methodologies for developing roadmaps. Most of them are described as short case studies and aim to serve as guidelines, rather than step by step processes to assist others in developing roadmaps. Two exceptions are the T-Plan, a product roadmapping approach, developed by the Cambridge Centre for Technology Management (CTM) (Phaal et al. 2003) and STAR methodology developed by Alignment (Gindy et al. 2009). In addition, TRM research is still in the development stage, especially in aspects such as process implementation, the operationalisation of TRM, the visualisation of a roadmap, and keeping the roadmapping process alive (Gerdsri, Kongthon, et al. 2008). Regardless of the type of roadmap, they all have some common goals: set targets, identify gaps, prioritise issues, identify R&D investments and paths for technology development, develop action plans and disseminate across the organisation or industry (Gindy et al. 2006). Overall, all roadmaps are trying to answer the following four questions first described by Albright : *1) 'know-why', 2) 'know-what', 3) 'know-how' and 4) 'know-when'* (Albright 2003). See Figure 24.

Technology roadmapping is different from foresight approaches, since it focuses on market opportunities rather than on social implications or threats (Carlsen et al. 2010).

(Schummer 2005) argues that "As a rule, they [the scientists] reduce the notion of 'societal implications' to the possible technological applications of their research."

Technology roadmapping can be either *technology-push* or *market-pull* or *both*. Technology-push methods start with a single technology and try to forecast its future evolution and potential opportunities for developing applications and products. This can be at both company and industry levels. Market-pull methods focus on the identification technology gaps and the respective critical technologies that need to be further developed in order to meet specific performance targets. It is predominantly used at company levels as product roadmaps, but it can also be used at sector levels.

Roadmapping drivers

The need for technology roadmapping is driven by several factors including:

- Rapid technological changes, increased complexity in technology and costs, more complex and dynamic nature of markets combined with global competition and uncertainty of forecasts (Phaal, O'Sullivan, et al. 2011).

- Drivers from the business environment, such as increasingly educated and demanding customers, increasingly shorter product life cycles and the increased introduction of new technologies (Groenveld 2007);
- More complicated, customised products and shorter product time to market (Bray & Garcia 1997).
- The need for strategic and long-term planning for technology-product-services development, so that firms achieve sustainable development and long-term survival, rather than short-term profits (Scott 2000), (Vatananan & Gerdsri 2011).
- Difficulty in aligning technology strategies with business strategies due to the lack of understanding of technology and its roles by corporate managers (Scott 2000).
- Difficulty in forecasting applications driven from a combination of advanced emerging technologies such as nanotechnology, biotechnology, information technology and cognitive science (Albright 2003).

As a result, firms have to be more responsive to these rapid technological changes, manage them more strategically, and support direct collaboration among the firm's IT managers and the business and product managers (Kappel 2001). Phaal and his colleagues (Phaal, O'Sullivan, et al. 2011) stress the need for holistic, integrated frameworks that would help companies and industries to manage innovations in different contexts, and that would support the innovation process from the initial idea and during the entire industry life-cycle. Similarly, (Gindy et al. 2009) adds the need for high technology firms to use methodologies in order to provide strategic management and long term planning of products and services and sustain completive advantage.

2.3.1 Roadmapping definitions

Following are some definitions provided by well-known researchers in the area of technology roadmapping.

Authors	*Definition*
Groenveld Philips Electronics (Groenveld 1997)	"In simple terms, roadmapping is a process that contributes to the integration of business and technology and to the definition of technology strategy by displaying the interaction between products and technologies over time, taking into account both short- and long-term product and technology aspects.''
(Garcia & Bray 1997)	"Technology roadmapping is a needs-driven technology planning process to help identify, select, and develop technology alternatives to satisfy a set of product needs. It brings together a team of experts to develop a framework for organizing and presenting the critical technology-planning information to make the appropriate technology investment decisions and to leverage those investments."
(Kappel 2001)	"Roadmaps are both forecasts of what is possible or likely to happen, as well as plans that articulate a course of action. Roadmaps can be used to align organizations in times of predictable change, but have limited insight into disruptive change."
(Kostoff & Schaller 2001)	"Therefore, an S&T roadmap provides a consensus view or vision of the future S&T landscape available to decision makers. The roadmapping process provides a way to identify, evaluate, and select strategic alternatives that can be used to achieve a desired S&T objective."
Naumanen (2001)	Defines a roadmap as "a map of presumed future and anticipated changes, comprising of illustrations of market trends, environmental changes, and technology life-cycles, linked together into tangible product line plans and considering the corporate objectives and competencies. A roadmap helps to create an "objective" shared vision

	with attention to changes in technology, socio-economic trends, new business opportunities, designs and processes."
(McMillan 2003)	"Roadmaps focus portfolio and business planning on the future"
(Strauss & Radnor 2004)	"Roadmap is a visual tool that identifies and describes specific customer requirement-driven technology clusters and specifies potential discontinuities and critical requirements related to technology decisions"
(Walsh 2004)	"Technology roadmapping has been defined as: Technology roadmapping is a needs-driven technology planning process to help identify, select, and develop technology alternatives to satisfy a set of product needs. It brings together a team of experts to develop a framework for organizing and presenting the critical technology-planning information to make the appropriate technology investment decisions and to leverage those investments".
(Grossman 2004)	"Technology Roadmap provides a framework for meaningful discussions between key stakeholders about both the development schedule and funding issues."
(Lee & Park 2005)	"Technology Roadmapping is designed and developed for the following three uses: forecasting, planning, and administration.
(Lee & Park 2005)	"Technology roadmap supports strategic management of technology. At the industry level, it helps to forecast technological future trends based on either exploratory methods or normative approaches. At the corporate level, it provides a graphical means for exploring and communicating the relationships among markets, products, and technologies over time."
(Elliott 2005)	"Technology roadmaps are a snapshot of how the future seems now and need to be kept alive by being revisited and refreshed on a regular basis."
(Gindy et al. 2008)	"At the enterprise level, technology roadmapping is primarily a management tool to improve the enterprise's strategic technology planning processes by aligning technology acquisition to company strategic objectives derived from market and business drivers. In addition, the team-orientated technology roadmapping process also supports consensus building".
(Amer & Daim 2010)	"Technology Roadmapping (TRM) is a growing technique widely used for strategy planning and aligning technology with overall business objectives. Technology roadmaps are extensively used in many diverse fields at product, technology, industry, company and national levels."
(Wells et al. 2004)	"Technology-roadmapping is a process and communication tool to aid strategic decision-making…. TRM is an important tool for technology planning and coordination at strategic level, helping senior managers to make better technology investment decisions"
(Ahlqvist et al. 2012)	"Roadmapping is considered both as a line of strategic thought and as a process methodology. Roadmapping combines different modes of knowledge with specific activity layers. We propose that principles of technology roadmapping could be applied in building the strategic capacities and constructing the horizontal foresight function inside a research and technology organisation (RTO). We present a diversified roadmap concept that adapts the scope of traditional technology roadmapping and widens its horizon towards such directions as visionary strategic management, network building and development, organisational learning and adaptation."
(Jin et al. 2015)	The technology roadmap is defined as a medium- and long term technology planning methodology to derive products and technologies that need to be developed to meet the future demand and to select the best alternative technologies based on the future market forecasts. In other words, the technology roadmap is one of the methods to support the strategic management of technology, exploring the relationships among organizational goals, technical resources held by the organization and changing market opportunities.

Table 3: Roadmapping definitions

As it is evident from the above definitions, TRM is often described as a process to manage technology planning and align it to business strategy, product and service development (Amer & Daim 2010);(Daim & Oliver 2008);(Amadi-Echendu et al. 2011) ;(Lee 2009);

(Dissel et al. 2009); (McCarthy 2003); (Lee et al. 2009) ; (Kostoff & Schaller 2001); (Phaal et al. 2002) ; (Groenveld 1997); (Wells et al. 2004) .

Technology planning is defined by (Gindy et al. 2009) as "a structured process through which an enterprise translates its business and technology drivers to decisions and actions that shape and guide its technology investment decisions. In order to ensure that technology development projects deliver sufficient business benefits, an enterprise needs systematic and effective processes to align technology development projects with its strategic vision and goals, its market strategy and support its product and technology strategies."

In addition, roadmapping is predominately described as a needs (market-customers) driven approach, that aims to bring consensus on the new product/services development in case of product/company roadmaps or identify and explore new technology trends, in case of industry/sector roadmaps. In case of company roadmaps, a vision is usually predefined by corporate goals. The approach aims to facilitate a long term planning. (Kappel 2001) and (Jin et al. 2015) stress the forecasting nature of the roadmapping process, while Lee and Park acknowledge that roadmapping can use both exploratory (what can happen) and normative (what should happen) approaches. (Ahlqvist et al. 2012) recognise the need for including foresight methodologies for developing research roadmaps while (Saritas 2013) and Naumanen as cited by (Leonie Project 2005) add the need to take into account socio-economic changes when building the roadmap and not just market and technology drivers. Phaal, Farrukh and Probert (Phaal et al. 2009) add that roadmapping is a dynamic framework, which assist in the exploration, mapping and *evolution of a complex* system and provides an innovation and actionable strategy for its development and adoption. (Yoon 2010) and (Zhang et al. 2013)emphasise the use of visualisation tools for building a roadmap. (Walsh 2004) and Kostoff, Boylan and Simons (Kostoff et al. 2004) provided models for building TRM for disruptive technologies.

The researchers also define roadmap as an approached useful for companies, as well as entire sectors or industries. We can conclude that Roadmapping, as a methodology to create a roadmap, is a holistic collaborative strategic planning process, which enables us to derive concrete actions, in order to manage technological innovations. Just like any other documented strategy, the roadmap as an end-result should be continuously tested and improved. Moreover, its success is measured against how effectively it has been communicated to and recognized by the relevant stakeholder groups. Hence, the value of Roadmapping lies largely behind its *capabilities to foster and enhance consensus building* among the corresponding stakeholder communities or within the company. In addition, *roadmaps are a participatory (social) process*, during which, the participants are sharing explicit and tacit knowledge in order to create, manage and structure new knowledge together. In that respect roadmaps are also regarded as knowledge creation process for the communities that develop them (Li & Kameoka 2003); (Yasunaga & Yoon 2004), (Kamtsiou et al. 2006). Some of known networks and groups and companies focusing on the topic are:

- MATI: Management of Accelerated Technology Innovation. The North-Western University School of Roadmapping – Kellogg school managed by Professor Michael

Randor. Currently changed to GATIC (cooperation with Japan Advanced Institute of Science and Technology, and ETH Zurich) (GATIC n.d.).

- EIRMA working group: European Industries Research Management Association TRM Working Group (EIRMA 2011).
- TRMUG: Technology Roadmapping User Group (IFM n.d.).
- Sandia National Laboratories: Strategic Business Development Department Sandia National Laboratories, researchers: Marie L. Garcia Olin H. Bray (SANDIA 2015).
- METI's (Ministry of Economy Trade and Industry) Strategic Technology Roadmapping Initiative (Japan); Areas Information and Communications, Environment and Energy, Life Science, Manufacturing (METI n.d.)
- NEMI (National Electronics Manufacturing Initiative): Technology Roadmap addressed the common needs for information products to connect to information networks such as NII (National Information Infrastructure) (INEMI 2015).
- Semiconductor Industry Associations of USA, Europe: International Technology Roadmap for Semiconductors (ITRS - SIA) (SIA 2014).
- MIT Information Technology Governance Committee (MIT n.d.).
- Motorola (GALVIN)
- Philips Electronics (GROENVELD)
- Lucent Technologies (ALBRIGHT; KAPPEL)
- General Motors (GROSSMAN)

2.3.2 Roadmapping Formats

Figure 24 is the typically generic roadmap structure mostly used today. It is a time-based chart, comprising a number of layers that usually include both commercial and technological perspectives (Phaal et al. 2009). Such structure enables the evolution of markets, products and technologies to be explored, together with the linkages and discontinuities between the various perspectives (EIRMA 1997). It is a *tabular format of a multilayer time-based chart* showing how the various Roadmapping elements are aligned and connected. It provides a methodology to integrate technology and business planning to a single graphical format close to a combination of Gant and PERT diagrams (Phaal et al. 2009).

Although Roadmaps can take various forms, they all try to answer 3 basic questions (Albright 2003), (Phaal et al. 2009).

1. Where we want to go?
2. Where are we now?
3. How we can get there?

Usually the question "Where we want to go" comes before the question "where we are now", since Roadmaps are usually driven by a future vision or a specific desired scenario. Where we want to go, also determines what is relevant in the present.

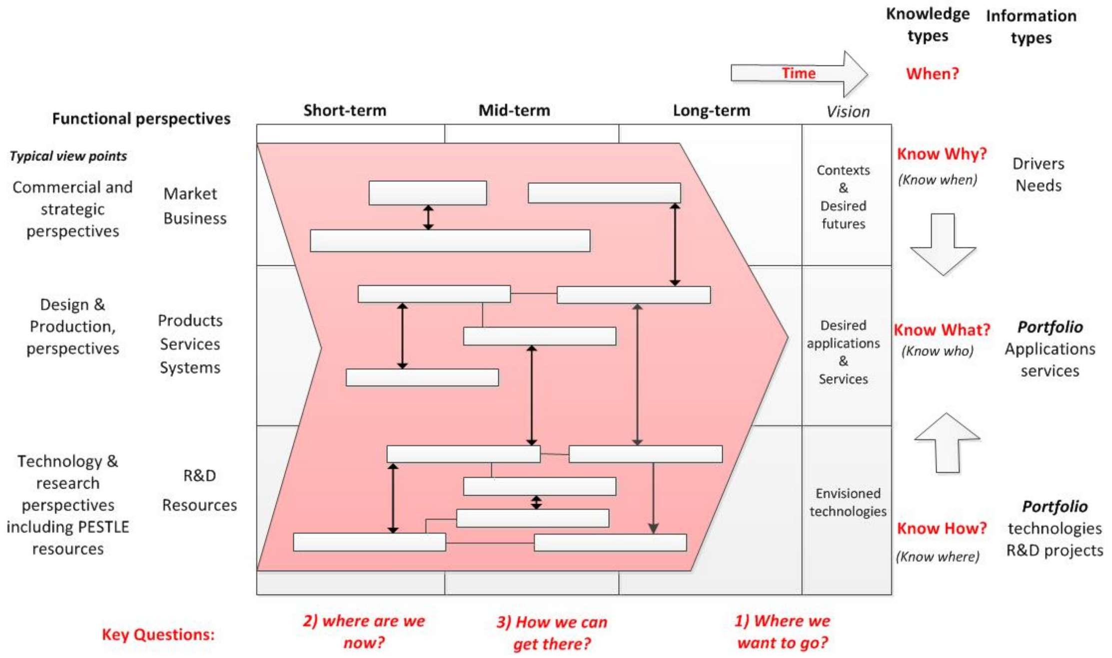

Figure 24. Roadmapping critical framework. Figure Based on: EIRMA (Groenveld 1997) from figure 2., p. 51 and from IfM (Phaal et al. 2009) from figure 1, p. 287

The top layer relates to the commercial and strategic perspectives including their PESTLE drivers. It is concerned with the purpose of *"why"* we are developing the Roadmap. Related information types are market analysis and competitor activity, customers' needs, market drivers, corporate (or industry) vision and strategy, etc.

The middle layer is concerned with the design and production perspectives, and the actual applications and systems we are aiming to develop, *"know what"*. A portfolio of applications and services are the information types typically produced in this layer.

The bottom layer relates to the technology and research perspectives and to all resources that provide the "*how*" to develop the applications and systems of the middle layer. In this layer, we need to map technology elements to solutions capabilities and produce a portfolio of technologies, R&D projects, and other related resources needed such skills, competencies and abilities (Phaal et al. 2005), (Phaal et al. 2009).

This Roadmapping structure provides *a visual way* to present the evolution of markets, products and technologies, including the linkages and gaps between the various perspectives, resources, competencies and capabilities.

In reality, until today, a standard methodology for roadmapping doesn't exist or a standard Roadmapping process. The different layers of roadmapping chart are customisable depending on the *type of roadmap* (industry, firm, science/research, sector, etc.) and the *type of* *innovations* (disruptive, systemic, linear, etc.). This type of chart is used predominately by companies and industry for visualising product roadmaps.

(EIRMA 1997) has defined *5 main components* in roadmapping:

- *Time*: differs depending on the type of roadmap. For product roadmaps usually time scope is 2 to 3 years, while for industry, sector and R&D roadmaps is from 10 to 15 years.
- *Deliverables*: The desired performance characteristics of the product or service and their intermediate targets.
- *Technologies*: the groups of technologies and their interactions needed to achieve the deliverables.
- *Skills/Science/Know-how*: required to develop the technologies.
- *Resources:* including human, intellectual, physical and financial.

Zurcher and Kostoff define four layers starting from top :a) "requirements", b) "capabilities", c) "development" and d) "research" (Zurcher & Kostoff 1997).

Saritas & Aylen (2010) argues that a typical roadmap structure is formed by four or five layers. These layers can have different attributes based on the objectives, contents and orientations of the roadmaps. A market oriented roadmap for example can have five layers such as: a) "market", b) "product", c) "technology", d) "R&D programmes", and e) "resources", showing capital investment, supply chain and staff/skills requirements on a timeline. Most roadmaps consist of *nodes and their attributes*, as well as *linkages between the nodes, and their attributes* (Saritas & Aylen 2010). These elements can be visualized using different formats, including, multiple layers, bars, network diagrams and flow charts. Other formats include tables, graphs, pictorial representations, a single layer, and texts. (Jin et al. 2015) have identified eight types of graphical formats for roadmaps: multiple layers, bars, tables, graphs, pictorial representations, flow charts, single layer and text. However, the Roadmapping approaches differ in terms of their aspects, artefacts, formats, layers and perspectives. Figure 25 Phaal et al. 2004b) and Figure 26 (Lee & Park 2005) shows examples of standardised roadmaps (Phaal et al. 2004b).

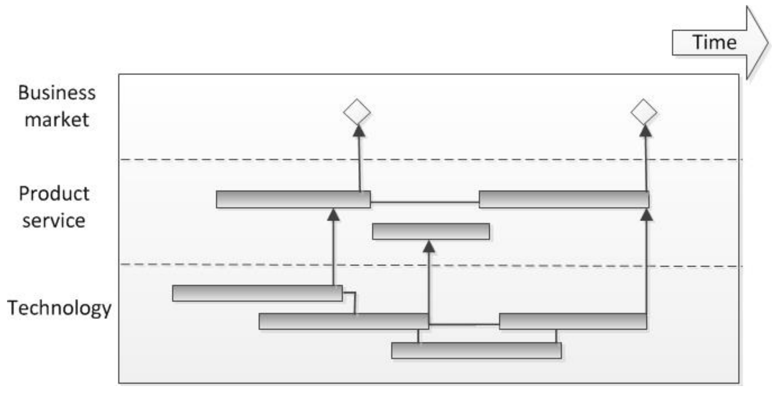

Figure 25: Schematic technology roadmap (Phaal, C. J. P. Farrukh, et al. 2000) from figure 5., p. 60

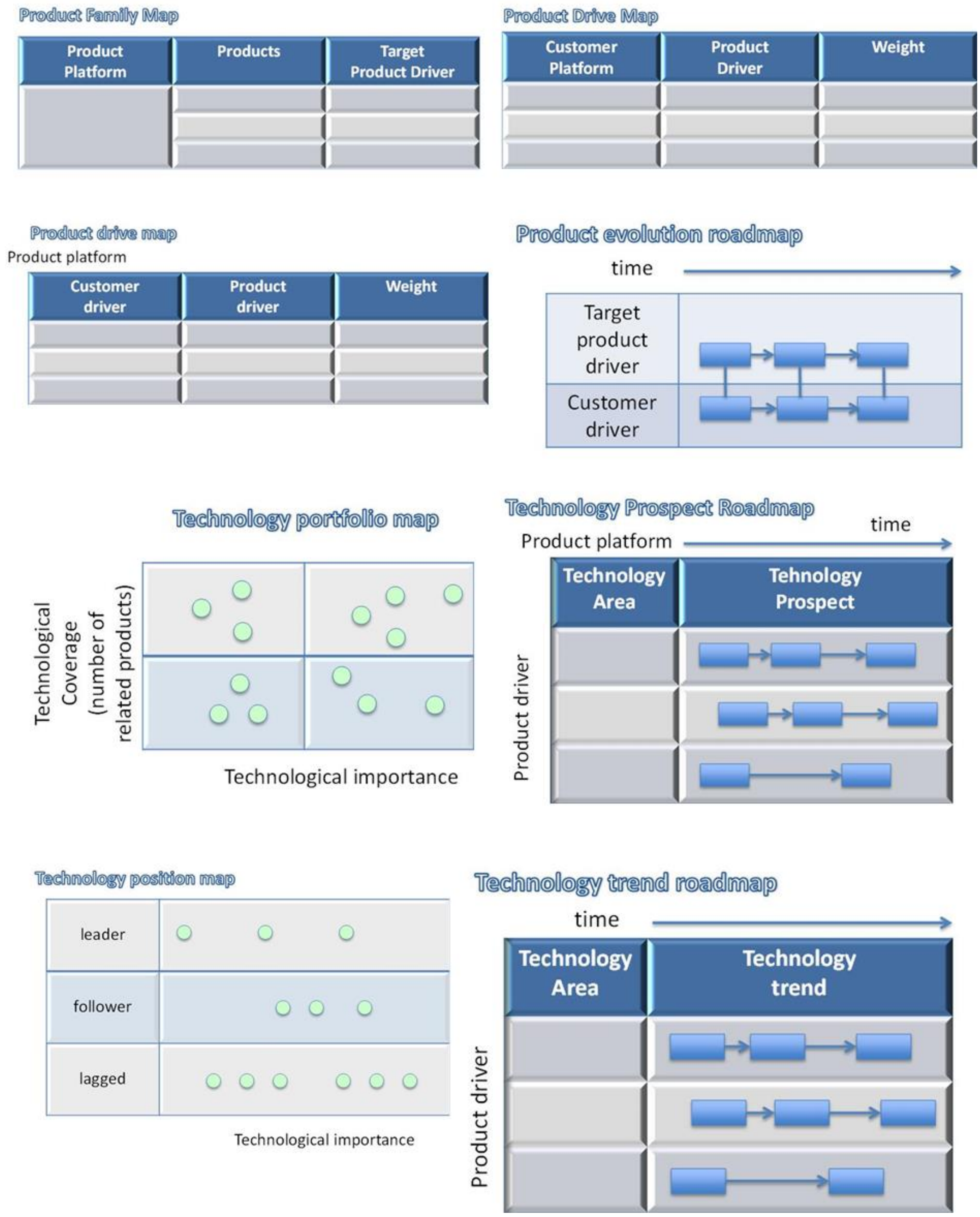

Figure 25. Standardized roadmap formats, Adapted from (Lee & Park 2005), (Phaal et al. 2004b).

2.3.3 Roadmaps taxonomy

Various roadmap types are discussed in the literature. According to (Radnor 1998) technology, product, and related forms of corporate and industry Roadmapping are being implemented gradually in large centred firms. Table 4 groups the various categorizations from different researchers. Industry Canada Initiative has published a guidebook for government employees on Roadmapping (Industry Canada 2007). Another taxonomy was created during the 1998 technology roadmap workshop (cited by (Kostoff & Schaller 2001). Kappel (Kappel 2001) has classified roadmaps according to their *'accuracy'* and *'influence'* dimensions, as shown in Figure 27. (Phaal et al. 2004b) classified technology roadmaps according to their purpose. In addition, Yoon, Phaal and Probert (Yoon et al. 2008) defined six categories of roadmaps, which were derived from the matrix shown in Figure 26.

Industry Canada Initiative	1998 Roadmapping workshop	Yoon et al.	Phaal & Farrukh	Kappel
	cross-industry roadmaps (e.g., Industry Canada initiative)	cross-industry roadmaps (Industry/ Cross industry & Normative)		
industry technology roadmaps (driven by market requirements)	industry roadmaps (e.g. International Technology Roadmap for Semiconductors)	industry roadmaps (Industry/ Cross industry & Exploratory)	long-range planning roadmaps (usually at as sector or national levels, assist for long term planning horizons)	industry roadmaps (set industry expectations)
science and technology roadmaps (driven by emerging technologies)	science / research roadmaps e.g., science mapping)	science/research (national/ international and exploratory)		science & technology roadmaps (set industry targets)
	technology roadmaps (e.g., aerospace, aluminium)	technology National/ International & Normative		
product roadmaps (technical processes and related opportunities and risks to develop products)	product-technology roadmaps (e.g., Lucent Technologies, Philips International)	product technology roadmaps (Firm/project & exploratory)		product technology roadmaps (align decisions with trends)
	product roadmaps (e.g., Motorola, Intel)	product portfolio roadmaps (firm/project & normative)	product planning roadmaps (integrates technologies choices in manufacturing)	Product roadmaps (schedule products introductions)
program roadmaps (driven by emerging issues)	project / issue roadmaps (e.g., for project administration)”		programme planning roadmaps (relate directly to project planning & implementation of strategy).	
			Process planning knowledge management roadmaps (focused on a particular process area such as product development, integration planning)	
			Service/capability	

			planning roadmaps (technologies supporting service based enterprises)	
			Strategic planning roadmaps (evaluation of threats and opportunities at business levels)	
			knowledge asset planning roadmaps (aligning knowledge assets and knowledge management initiatives)	

Table 4: Roadmaps taxonomy based on (Industry Canada 2007),(Kostoff & Schaller 2001), (Kappel 2001), (Phaal et al. 2004b), (Yoon et al. 2008)

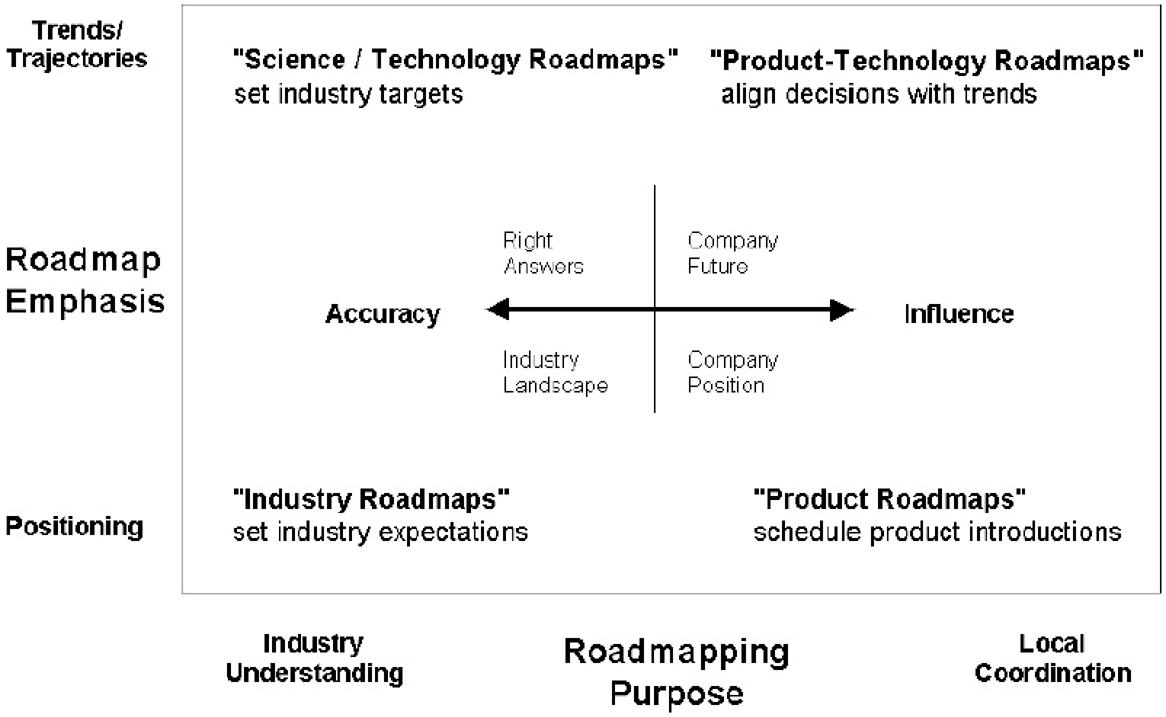

Figure 27. Kappel's Roadmapping Taxonomy. (Kappel 2001) from figure 1, p.40.

The *horizontal axis* in Kappel's taxonomy, differentiates between Roadmapping purpose, for example whether a roadmap is developed for the generation of insights at the industry level or for coordination at the company level. The *vertical axis* differentiates the roadmaps themselves by their content emphasis, which can be placed either on specific trends or on positioning within an industry (Kappel 2001).

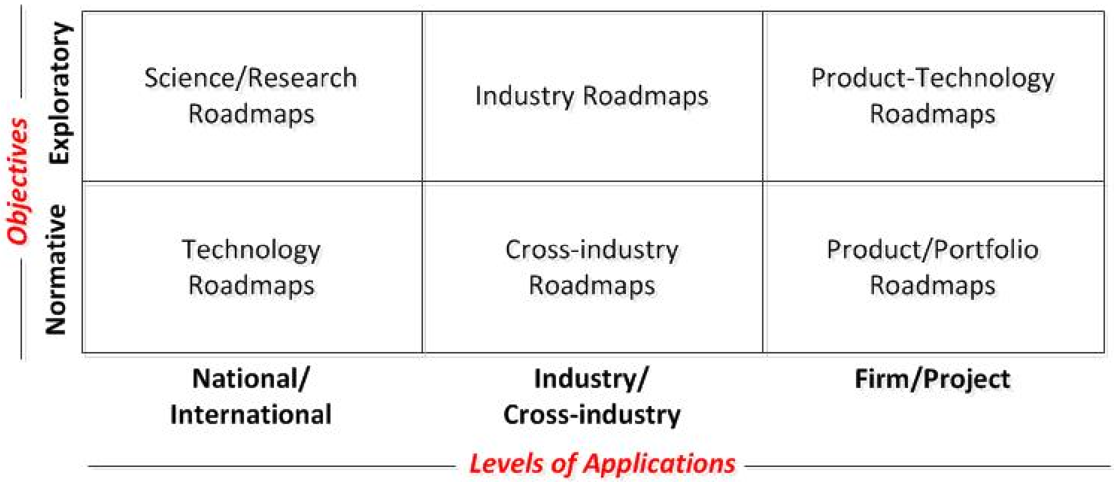

Figure 26. Morphology analysis for technology roadmapping. Adopted from (Yoon et al. 2008) from Figure 1, p.55

2.3.4 Roadmapping Approaches

Literature review and current practices suggest a standard process for Roadmapping doesn't exist, but Roadmapping must generally be customized to suit a particular application and partly to the difficulty of accomplishing such customization. Overall, the Roadmapping process aims to provide us with information on "where we want to go" (visions/desired future) and "where we are now" (current state), so that we will be in a position to determine "How we can bridge the gaps between the future and the present".

(Kostoff & Schaller 2001) identified three fundamental Roadmapping approaches: expert-based and computer-based, and their combination.

Expert-Based Approach

This is approach is based on expert teams who identify and develop attributes for the nodes and links of the roadmaps. The paradox of this approach is that experts develop a roadmap which will be based on future and new expertise, while the experts themselves are having expertise that are linked to today's knowledge. Moreover, this is a top-down approach, which is not based on stakeholder's requirements, thus making it difficult later to gain their support for adoption. Finally, this approach suffers from the street-lamp syndrome that is often observed in experts' assessments. In the sense that they can only see the specific area of their expertise and not the broader picture, therefore, quite biased.

Computer-Based Approach (Bibliometric, mining, Big Data technologies)

This approach relate to big data analysis and techniques such as bibliometric, data and text mining, social network analysis (SNA), agent based predictive models, patent analysis, desktop analysis, simulation scenarios, etc., the results are classified and correlated and opportunities stemming from these new possibilities are identified. (Kostoff & Schaller 2001) argue that this approach is more objective and does not suffer from the bias and personal motives and agendas associated with the experts' approach. But it is relative new and there are not enough good practices yet. As derived from a US based Mckinsey report (Manyika et al. 2011) published on 2011, big data approaches are expected to be more successful in areas that large digital data are already exist (e.g.in computer and electronic products, information, health care and insurance, finance sectors). As shown in Figure 29, in US the education sector (Cluster C) has experienced negative productivity growth partlially due to lack of data-driven mind-set and available data and partly due to strong systemic barriers to increase productivity. Nevertheless, even when digital data exists, the results need to be interrconnected and their cross-impact to be analysed, therefore, people's intuitions and past experience are important for the final analysis.

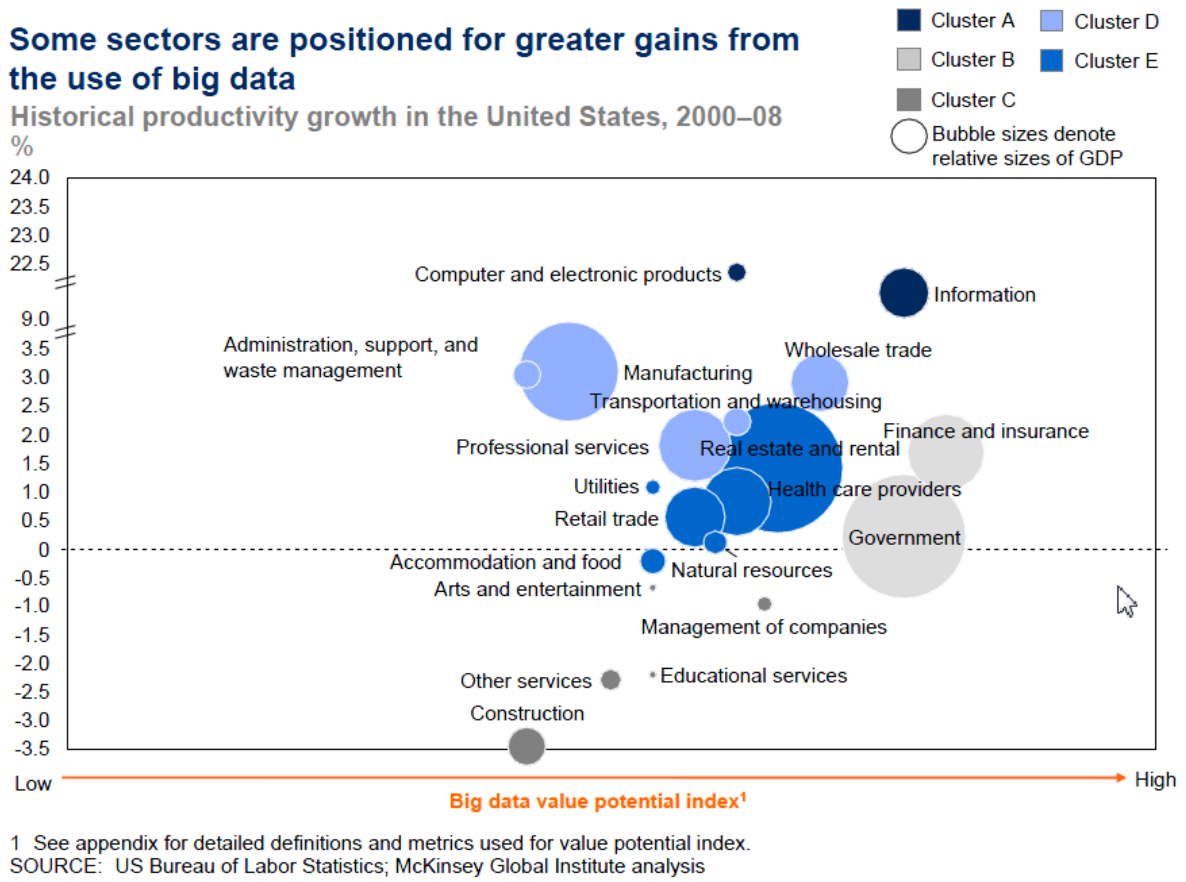

Figure 29. Big data value potential index. Source: (Manyika et al. 2011) Exibit 2, p.9.

Computer based approach to Roadmapping should not be confused with roadmap databases (digitized roadmaps) or with applications (software) to create roadmaps.

Hybrid Approach

As said before one, the computer based approach has limitations due to the lack of people's interactions which are fundamental in roadmapping methodology. As cited by Kostoff & Schaller 2001) and Radnor warns that "Companies want to 'mechanize' Roadmapping, but much of it remains off the books. Roadmapping is political and involves negotiation and re-negotiation". The most recent roadmapping approaches are mixing both experts based and computer based methodologies. A bibliometric analysis is usually applied in the beginning in order to map the knowledge evolution and expert networks and then, it is later combined with experts workshops in order to further validate, and link knowledge (See examples of bibliometric approaches applied by TEL-map, in case study section 6.3.2).

Customizing Roadmapping

The two key elements of customization in a given Roadmapping context are *architecture* and *process*. The core of the planning phase is a design activity in which both the roadmap architecture (time and layers) and Roadmapping process (macro process and micro process) need to be considered in parallel. The T-Plan roadmapping methodology, which was developed by IfM (IFM n.d.) Technology Roadmapping User Group in Cambridge based on a generic roadmap architecture is used as a basis for customization (Dissel et al. 2009) (Phaal & Muller 2009) (Phaal, C. J. Farrukh, et al. 2000).

2.3.5 Micro-Meso-Macro levels in roadmapping

In Micro (company) level roadmapping, the desired future is driven by corporate goals set up by managers, market requirements and customer drivers. While this is typically a given at the outset, the task is to work out how to get there. The focus is on exploring the evolution of markets, products and technologies. Micro-level could also refer to technology innovations that are creating novel configurations.

Macro (industry, research, science and technology) level roadmapping often seems to be driven by socio-economic changes and anticipated technology developments, a method very close to foresight approaches.

Meso-level, multi-organisational roadmapping, starts with participants setting out and sharing their individual future visions and goals and then establishing and hopefully growing their common intersect. It considers areas of common needs, or common visions, usually from a group of stakeholders in a sector who face volatile or adversarial conditions (Phaal et al. 2004b),(Lee & Song 2007) , (Garcia & Bray 1997),(Zhang et al. 2013).

2.3.6 Tools and methods for Roadmapping development

Management tools, technology analysis tools, forecasting tools, and foresight tools are used in the Roadmapping development, in different degrees and combinations. Table 5 provides a list of some of the most commonly used methods in roadmapping and the respective researchers who have used them in their roadmapping approaches:

Strategy analysis	(Pagani 2009); (Fenwick 2009)
SWOT	(Pagani 2009); (Fenwick 2009); (Phaal et al. 2005) (Kamtsiou, Olivier, et al. 2013), (Kamtsiou et al. 2007), (Kamtsiou et al. 2010)
Analytic hierarchy process	(Fenwick 2009); (Gerdsri & Kocaoglu 2007)
Competitive features matrix	(Fenwick 2009); (Gerdsri & Kocaoglu 2007)

Delphi; PESTLE;	(Fenwick 2009); (Saritas & Oner 2004); (Phaal et al. 2005); (Kameoka et al. 2003); (Kamtsiou, Olivier, et al. 2013)
Eco-design	(McDowall & Eames 2006)
Five forces analysis	(Fenwick 2009), (Fenwick et al. 2009); (Pagani 2009); (Phaal et al. 2005)
Integrated management model	(Saritas & Oner 2004)
Morphological matrix	(Yoon et al. 2008)
Perceptual map rank valuation	(Fenwick 2009); (Fenwick et al. 2009)
Portfolio management	(Oliveira & Rozenfeld 2010) (Phaal et al. 2006)
QFD Quality Function Deployment	(An et al. 2008); Lee, (Lee et al. 2009); (Groenveld 1997); (Groenveld 2007);
Scenarios	(McDowall & Eames 2006); (Pagani 2009); (Passey et al. 2006); (Strauss & Radnor 2004); (Yamashita et al. 2009); (Lee et al. 2010) (Lee et al. 2014) (Kamtsiou et al. 2012)
Technology development envelope (TDE)	(Gerdsri 2005); (Phaal et al. 2006)
Technology management tools	(Farrukh et al. 2003); (Phaal et al. 2006);
Value proposition	(Fenwick 2009); (Kamtsiou, Olivier, et al. 2013)
Experience curve	(Willyard & McClees 1987)
concept visioning	(Passey et al. 2006), (Kamtsiou et al. 2006)
Bibliometric	(Kostoff & Schaller 2001); (Kostoff et al. 2004); (Kostoff et al. 2005); (Zhang et al. 2013); (Gerdsri, Kongthon, et al. 2008); (Lee et al. 2009), (Zhang et al. 2013), (Kamtsiou, Olivier, et al. 2013)
Bayesian belief network	(Lee et al. 2010); (Suharto 2013b);
Database Tomography (DT)	(Kostoff et al. 2005)
Patent Analysis	(Lee et al. 2008)
Innovation matrix	(Groenveld 2007)
Change management methods	(Gerdsri, Assakul, et al. 2008); (Gerdsri et al. 2010); (Amadi-Echendu et al. 2011); (Kamtsiou, Olivier, et al. 2013)
Growth curves	(Walsh 2004), (Kamtsiou, Olivier, et al. 2013)

Table 5. Methods used in roadmapping, compiled from literature review

Digital tools to build digital roadmaps are still very limited due to the fact that roadmapping process needs to be customised in each case. Still gathering, processing and sharing information is a crucial component of any strategic planning process. This involves numerous sources and stakeholders within and outside of an organization e.g. customers, suppliers and competitors. A common information framework architecture and intelligence management system is crucial to this collaborative process. The Enterprise Roadmap Management System (ERMS) developed and used by Motorola Corporation provides common software and information architecture for all collaborators of Motorola. This gives Motorola associates the ability to create, build and share their technology visions, products and business strategy roadmaps throughout the corporation (Richey & Grinnell 2004).

The Centre for Technology (CTR) Roadmapping at Purdue University has recently opened its online service including its “Roadmap Archives”. One of the objectives is to be able to link various roadmaps much in a similar manner that ERMS is currently used by Motorola. The CTR service uses Stratevas' Geneva Vision Strategist software Roadmapping tool. Although some specialized software for Roadmapping is currently available (for example Geneva Vision Strategist (Alignent n.d.), Aha! (Aha! Labs n.d.), ProductPlan (ProductPlan 2015), most of those are specific to product or company roadmaps. Still the majority of roadmaps are still being prepared using conventional spread sheet, word-processing and presentation tools. In the TEL-Map case study, we used free online collaborative tools such as C-Maps, Conzilla, GoogleDoc, and a dedicated website. Types of free collaborative tools were preferred since the co-innovation group had already experience in using them and they were free.

2.3.7 Roadmapping benefits

Due to the nature of roadmapping exercise as a learning process, and its long term perspective, some benefits might need long time to become apparent.

(Garcia & Bray 1997) identified three major uses and benefits derived from technology Roadmapping.

- Roadmaps help develop consensus among decision makers about a set of technology needs,
- Roadmapping provides a mechanism to help experts forecast technology developments in targeted areas, and
- Roadmaps present a framework to help plan and coordinate technology developments at any level: within an organization (company), throughout an entire discipline (industry), even at cross-industry (national or international) levels.

Overall, the main benefit of technology Roadmapping is provision of information to help experts and companies to make better investment decisions. (Kappel 2001) argues further that the Roadmapping process not only produces more informed individual decisions, but it also brings with it better alignment of organizational decision making. It has a synergetic effect across functional teams (Brown & Hare 2001). By applying Roadmapping the organization is able to anticipate, identify and confirm changes in industry and technology to spot market, technology and research gaps (Phaal et al. 2003), (Bray & Garcia 1997). As a strategic decision making tool, the process of Roadmapping can identify potential technologies to meet business goals, provide integrated strategies and direction to support decision making (Albright & Kappel 2003), (Wells et al. 2004).

From the perspective of industry-wide or national Roadmapping, as opposed to company-specific roadmaps, technology Roadmapping:

- Provides a framework and mechanism for agreeing on research and development needs and priorities,
- Facilitates consensus building among industry members and their customers and suppliers,
- Assists in the coordination of on-going research and development,
- Helps focus and leverage the application of resources, and
- Supports the strategic transformation of organizations and industries

- It also serves as a mechanism to integrate and take into account societal, political, economic perspectives with technology planning and industry/sector objectives.

It should be noted that the true extent of the benefits of Roadmapping has yet to be proven. As pointed out by (Radnor 1998) when integrated with Foresight approaches, roadmapping provides a mechanism to support strategic planning and innovation management. It provides mechanisms to integrate foresight approaches such as forecasting and scenario planning with strategic planning, market and competitive intelligence as dynamic systems frameworks.

Roadmapping as Knowledge and Innovation management:

According to (InKNOWvations 2015) "The main difference between roadmapping and other business processes such as strategic planning, portfolio management, new product development, competitor analysis, benchmarking, project management, etc. is that roadmapping is the only one that provides a bridge between organisations, functions, processes and time". Thus, roadmapping has an integrative power across functional communications and processes in an organisation or in a sector, which are crucial to innovation and development (Willyard & McClees 1987), (Groenveld 1997), (Lee & Park 2005).

2.3.8 History of the Approach

Technology roadmapping was first introduced by Motorola in the 1970's as a framework to map the knowledge flows within the firm and it was first published by Motorola in 1987. During the late 1980s, Technology Roadmapping was developed to help companies anticipate and clarify resource and performance requirements and to plan and systematically manage and integrate complex projects (Willyard & McClees 1987); (Barker & Smith 1995). Motorola today produce and maintain a database of digital roadmaps, using the "Vision Strategist" software. In the beginning of 1990s, the Roadmapping approach has been increasingly applied at network and industry levels. (Phaal et al. 2009) have identified more than 1,500 public domain roadmaps related to diverse domains such as science, technology, industry and policy such as: aerospace, astronomy, chemistry, construction, defence, earth sciences, electronics, energy, healthcare, manufacturing, physics, software, transport and other. This kind of Industry level Roadmapping was usually sponsored and organized by government agencies, trade associations and research networks. This is a different perspective from the business and commercial approach predominant in the product and firm roadmaps. Usually the industry level Roadmapping approach utilise foresight methods such as scenario planning, Delphi-based processes in order to develop expert-based views of future states, goals and required actions. Examples of such Roadmaps are the ITRS roadmap for semiconductors (ITRS 2011) and the EU funded projects time2learn, Bridges, and PROLEARN (Kamtsiou et al. 2006). Roadmapping as a research topic is a growing trend since over 59% of papers have been published in the last 5 years (Gerdsri, Kongthon, et al. 2008). Since the first Roadmapping paper from Motorola, up to 2000, most of the roadmapping studies were offered by companies. USA, UK and Japan are the three top countries in roadmapping publications. After 2000, the lead was taken by academia with emphasis in systematisation of TRM process and implementation approaches (Gerdsri, Kongthon, et al. 2008).

How Roadmapping has been evolving since first developed by Motorola

The first published Technology Roadmap (Willyard & McClees 1987) was the Motorola TRM roadmap. It provided a ten-year horizon chart for a car radio product, showing the product level (system level) functionality and performance, along with key technologies that would need to be developed or acquired, as a strategic product planning at corporation level. Early adopters of TRM included Philips and Lucent Technologies in the electronics consumer sector. *A key landmark* in the evolution of the approach was the development of the first *sector-level* (ITRS 2011), (Schaller 2001) initially in the USA and then internationally, where competitors collaborated to ensure that the whole sector benefited through common standards in infrastructure, and to ensure appropriate government funding and support. The *UN 2003 United Nations Roadmap* for peace in the Middle East shows that the Roadmapping approach has been noticed by Policy Makers at the highest levels (Phaal et al. 2005). Motorola, Lucent Technologies, Philips, BP, Samsung, LG, Rockwell, Roche, General Motors are few among many other companies that systematically use roadmapping in their technology planning (Lee et al. 2012).

Key milestones for the evolution of TRM methodology

Motorola

Roadmapping was developed in Motorola in the 19070s and the first paper on roadmapping was published by (Willyard & McClees 1987). Since then, Motorola uses roadmapping as a tool to link its individual roadmaps to a high level-meta roadmap. The approach uses roadmapping as a collaboration tool between the company's customers and suppliers, in order to identify gaps in both product offerings and customer needs and reduce uncertainty and costs. Motorola roadmaps include information on patents and on competitors and they can be accessed and up-dated online. *Motorola developed the Enterprise Roadmap Management System (ERMS)* (Richey & Grinnell 2004). Registered members of the Motorola Knowledge Community use the ERMS software in order to build their business strategy roadmaps and share a common framework on their visions, product offerings, solutions, and business strategies. It has long-term agreements with its main suppliers to use digital roadmapping, which is directly linked to Motorola's technology roadmapping system, *thus integrating roadmapping in its supply chain.* Motorola uses this software in order to gather and map strategic intelligence on its customers, suppliers and competitors via a common library of roadmaps. Motorola uses Vision Strategist and Vision Synergy software to produce and update its digital roadmaps. (DeGregorio 2000) stresses that the roadmap planning process should be linked and support key business decisions. Figure shows how Roadmapping in Motorola is integrated in its supply chain management. In this way, the firm is moving from the traditional just-in-time inventory supply chain management to a knowledge basis management, which reduces uncertainty in new product innovations, customer needs and market demands (Petrick & Echols 2004).

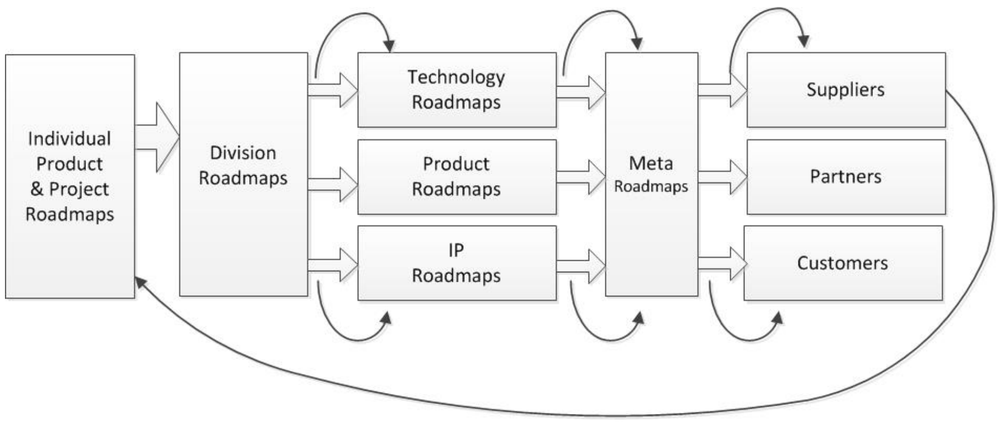

Figure 30. Integration of roadmapping and supply chain management in Motorola. Adopted from (Petrick & Echols 2004) from figure 4, p.93.

Similarly in 'Dynamic Roadmapping' framework, such integration ensures the collaboration and coordination of innovators' actions across the innovations' supply chains, and other value added actors and key users. In addition, such collaboration via roadmapping supports the identification and management of interdependencies that exist in the innovation process and ensures that everyone involved is coming on board. 'Dynamic Roadmapping' is looking at this integration at a meso level, forming a multi-organisational 'Dynamic Roadmapping' network across multiple organisations, suppliers, intermediaries (e.g. policy makers, distributors, re-sellers) and users/customers.

Sandia National Laboratories (Government Laboratories)

Garcia and Bray published a report on the "fundamentals of Roadmapping, based on their approach applied in Sandia National Laboratories in USA. For Garcia and Bray, roadmapping is a needs driven approach, which starts from the identification of complex needs that need to be decomposed, rather than driven by solutions. Therefore, it is a process used to identify technology gaps, and to coordinate the necessary R&D activities and investments to meet them, in order to build specific solutions, which are driven by market needs. The emphasis is on coordinating science and technology development, developing consensus, supporting technology forecasting in key areas and providing a framework for product roadmap planning. This allows managers to make more confident technology investment decisions, through their increased understanding of critical technologies, markets, and technology gaps, and to plan the associated research activities within and across organizations. In addition, Roadmapping is used as a communication strategic tool in order to support the marketing of technology internally and externally and position a firm in the industry (Bray & Garcia 1997).

(Bray & Garcia 1997) have identified three main roadmapping phases, which are still recognised as the most common categorisation for roadmapping phases till today (Walsh 2004)*: **a) preliminary activity, b) development of the Technology Roadmap, c) follow-up activity*** (see Figure).

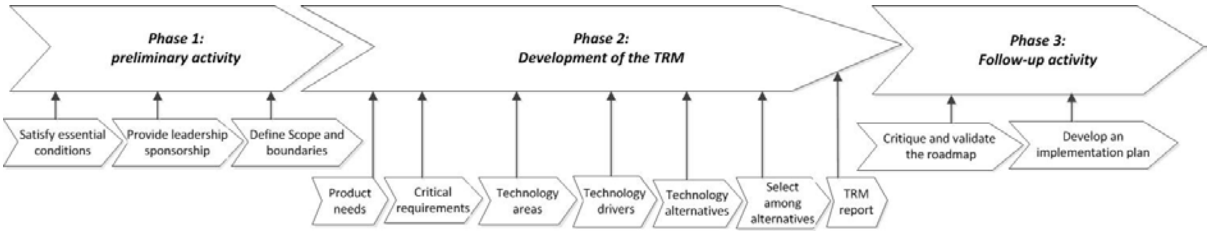

Figure 31. Technology Roadmapping (TRM) processes. Figure is modeled based on TRM process description in (Bray & Garcia 1997)

- *Preliminary activity includes 3 steps:* **(1**) Satisfy essential conditions. This includes description of conditions that are met or need to be met when developing the roadmap. In case of company roadmaps, the participation of different people who will bring different perspectives from several company departments needs to be ensured. In case of industry roadmaps, the participation of members from industry, academia, government, customers and suppliers need to be ensured. **(2)** Provide leadership/sponsorship. This involves the identification and commitment of the individuals or groups that will be responsible for the implementation and follow-up of the roadmap. In case of industry roadmapping, the industry (umbrella organisation, standards group, ministry or a trade organisation, etc.) should lead the effort and not a specific university, company or research centre. **(3)** Define the scope and boundaries for the technology roadmap. This involves specification of the time horizon (usually 10-15 years), existing vision, and justification of the roadmap. The scope of the roadmap should be also clearly defined. Industry roadmapping is much more complex in setting scope and boundaries, because of the complex needs involved and the inability of companies to collaborate.

- *Development of the technology roadmap activity includes 7 steps:* **(1)** Identify the "product" that is the focus of the roadmap. This involves identification and consensus on product needs. In case of uncertainty, the scenario methodology can help assess various options. **(2)** Identify the critical system requirements and their targets. The authors recognise this as a difficult task, but they do not provide detailed guidance. **(3)** Specify major technology areas. These are the critical system requirements needed in order to meet performance targets. **(4)** Specify the technology drivers and their targets. The next step is to transform the identified critical systems requirements into technology drivers, linked them to the identified technology areas. Alternative technologies selection will be based on these drivers. **(5)** Identify technology alternatives and their time lines. Selection of technologies should also accompany by a maturity schedule. **(6)** Recommend the technology alternatives that should be pursued. When selecting the technologies variable such as time, costs, performance, trade-offs, and disruptions, should be considered in the analysis of each technology. **(7)** Create the technology roadmap report. The report should include identification and description of each technology area and its current status, critical factors which could jeopardise the roadmap implementation, the areas not addressed in the roadmap, and the technical and implementation recommendations.

- *Follow-up activity includes 3 steps:* **(1)** Critique and validate the roadmap. An implementation plan must be developed after the roadmap is validated and accepted by the ones that will implement it. **(2)** Develop an implementation plan. **(3)** Review and update. This usually involves setting up periods for updates, e.g. once a year etc., rather than a process triggered by new developments (Bray & Garcia 1997).

They also made a distinction between TRM and issues oriented roadmap. The phases for issue oriented roadmap are depicted in the Figure Figure 2732 below:

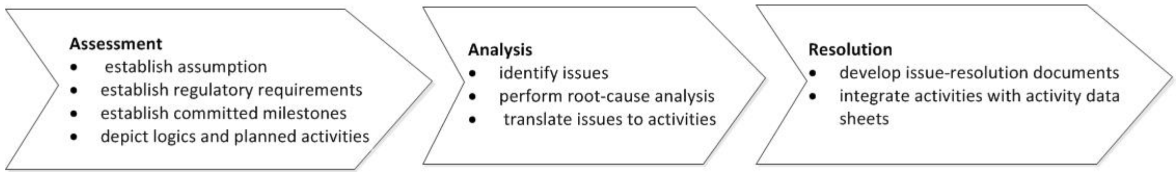

Figure 272. Phases of TRM issues oriented roadmap. Modelled based on (Bray & Garcia 1997)

Nevertheless, although a step-by-step approach was provided, it was all summarised in a short case study. In addition, they have mentioned that scenarios can be used in order to deal with uncertainty factors about the product needs, but a specific approach was not provided by the authors.

Philips Electronics & EIRMA

Another key milestone in the methodology development of TRM, as a product-technology type Roadmap, was the publication of European Industry and Research Management Association (EIRMA) and Philips' approaches to Technology Roadmapping (EIRMA 1997) (see Figure). Philips introduced the time based multi-layer chart type format that is the predominant roadmapping format till today (see Figure 24, EIRMA).

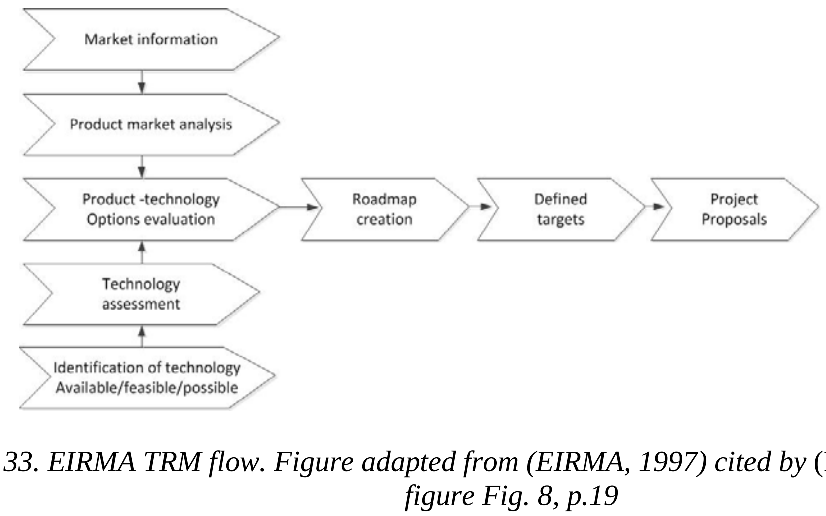

Figure 33. EIRMA TRM flow. Figure adapted from (EIRMA, 1997) cited by (Phaal et al. 2004b) *from figure Fig. 8, p.19*

Roadmapping is used by Philips Electronics in order to better integrate business and technology strategy and improve the product creation process at the concept and idea phases (Groenveld 1997). It used a 7-steps approach Figure 28;

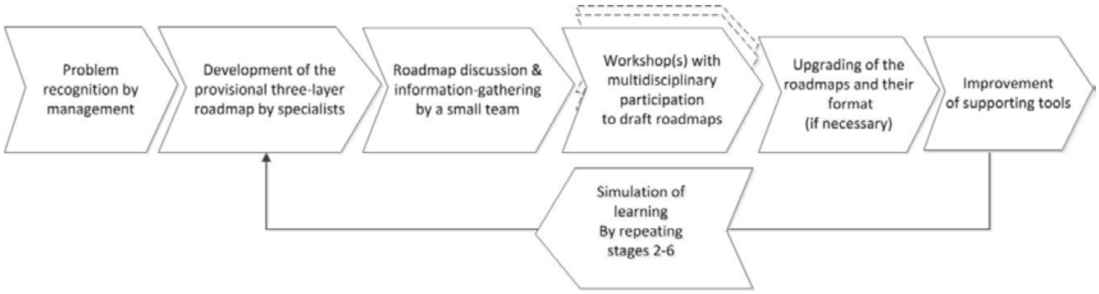

Figure 28. 7 steps approach TRM by Philips Electronics based on input from (Groenveld 1997)

Unlike the Motorola's one product specific development Roadmap, Philips methodology is more general to signify any component, product, system, or production process. The focus is on early product development, for the right market at the right time (Groenveld 2007). Groenveld stressed that the roadmap should start with a small team and later the team finds a leader who becomes the owner of the roadmaps and responsible for their maintenance and updating. In addition, Groenveld, similarly with (Kappel 2001)and (Albright & Kappel 2003) added the use of strategic planning tools for integrating technology in the roadmapping process. However, Groenveld description of the roadmapping approach was very short and not detailed. A method for the roadmaps maintenance was not provided either. (Albright 2003) first introduced the common framework via three questions: know-why, know-what, know-how and know-when. Finally, Groenveld 7 steps approach is predominantly top-down, starting from a problem which is predefined by corporate management.

Strauss & Radnor

Strauss and Randor identified the limitations of roadmapping approach to plan for innovations in volatile and rapidly changing systemic environments. Strauss, Randor and Peterson defined roadmapping as a top-down approach, used by management to link customer/market needs with opportunities, product quality and positioning of the firm. Furthermore, according to Strauss and Radnor, roadmapping is used as a method in order to link technological development to the firm's capabilities related to its business value chain (Strauss et al. 1998) . In 2004, they characterised current roadmaps as linear, meaning that they incorporate technology trajectories based on one straight line scenario. Therefore, roadmaps are difficult to develop, when planning in volatile environments which are characterised by rapid, systemic and unanticipated changes. They stressed that lack of explicit assumptions concerning future needs may shift the focus from the needs of the customers to the eloquence of the technology; and that important contextual factors related to roadmap might be missed. They were among the first to suggest an approach for developing company 'Dynamic roadmaps' in volatile environments based on the following steps (Strauss & Radnor 2004):

1. Identify corporate drivers and company profile relative to its industry
2. Specify underlying assumptions, company stress points, opportunity points, and flag items that may require further research or thought.

3. Assess drivers of change in the environment.
4. Assess strategic implications of the above.
5. Define initial issues for composite approach.
6. Develop scenarios based on these issues.
7. Create barebones roadmaps for each scenario.
8. Define checkpoints.
9. Consider significant variations in tasks, decisions, resource requirements, and resource availability in the other scenarios.
10. Define the "window" in which the emerging scenario can be fitted to a company strategy and identify the related resource requirements. Indicate a "fork" between the scenarios (and associated PERT charts) as needed.
11. Specify potential "flex" points where adjustments may be made.
12. For each scenario and strategy, translate the tasks, decision points, checkpoints, indicators, and external developments into a GANTT type chart.
13. Flesh out the roadmap (PERT and GANTT charts) for the most likely scenario.
14. Continually refine scenarios—and adjust roadmaps accordingly—as they come closer to reality.
15. With the frequency dictated by the intensity of change, regularly re-evaluate scenarios and repeat scenario and multi-scenario roadmap development process.

Although these steps summarized the integration of scenario planning and roadmapping, the two approaches were explained separately and a process based integration was not provided, or a detailed description of the approach. The authors recognised the need for roadmapping and scenario planning to be developed in parallel and to iterate with each other, but they did not offer a detailed approach. They mentioned that an integrated approach would depend on the company culture, organisational structure, current practices and the pre-existence of already developed roadmaps, and their urgency for implementation. Finally, this was an approach fitted for company –level roadmapping (Strauss & Radnor 2004).

The Cambridge Centre for Technology Management (CTM)

Phaal, Farrukh and Probert developed the T-plan process (Phaal et al. 2004a) (Phaal et al. 2003) for creating technology roadmaps at a firm level. In 2001, T-Plan "fast-track" Roadmapping guide was published by (Phaal et. al., 2001) and the TRMUG (Technology Roadmapping User Group (IFM n.d.) was founded and coordinated by the Centre for Technology Management at Cambridge University. This guide focused in Roadmapping as a visual framework to support strategy and innovation. Since, still at the firm level, Roadmapping is seen from the company's business contexts (Strategic Management tool). In this case, the Roadmap in driven by the organization's visions, customers and market needs, aiming to link technological and commercial perspectives. This was the first detailed description of the roadmapping approach, including step-by-step processes, workshops descriptions, and templates. It became very well-known and implemented by companies in different industries. The method influenced several researchers such as: (Gerdsri & Kocaoglu 2003); (Gerdsri 2005); (Saritas & Oner 2004); (Lee et al. 2007) ; (Dissel et al. 2006) Similarly to Sandia approach, this is a workshop-based methodology based on three stages: a) planning stage, b) roadmapping stage, c) roll-out stage. It is based on a fast-track roadmap implementation phase. This is a product-planning based roadmapping, for companies and not applicable for sector level planning. The process steps are shown in Figure 29 below.

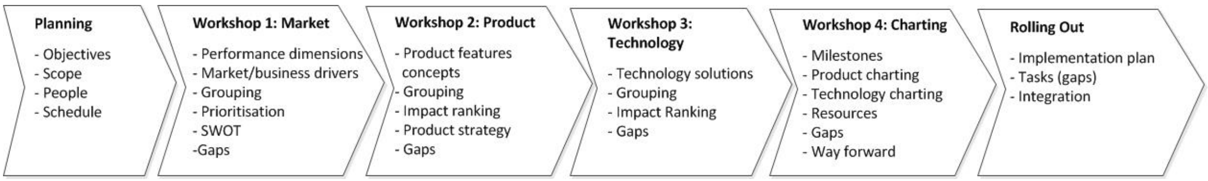

Figure 29: T-Plan process framework. Figure adapted from (Phaal 2004) *from figure 6, p.42*

This process results in a 'first-cut' roadmap, which includes key knowledge gaps and implementation factors (see Figure 30).

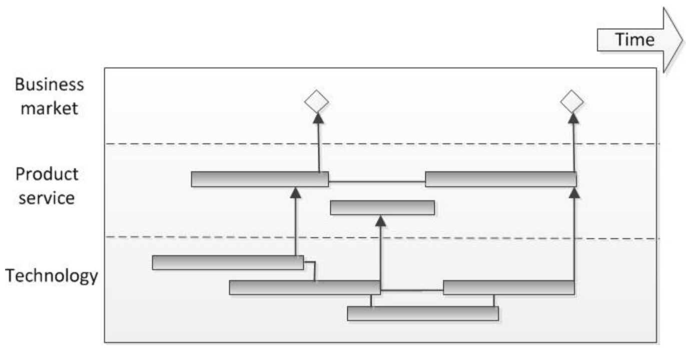

Figure 30 Roadmap schematic. Figure adopted from (Phaal, C. J. P. Farrukh, et al. 2000) from figure 5, p. 60

Lucent technologies - Richard Albright and Tom Kappel

Richard Albright and Tom Kappel describe how product-technology roadmapping was implemented in *Lucent technologies, a large telecommunication firm*, for assisting in corporate technology planning. The Roadmap was deployed across the corporation and linking market strategy to product plans and to technology plans. It identified needs, gaps, strengths and weaknesses. It enabled the development of corporate level technology plans and focused on long term planning. It also improved the communication and ownership of the plans, through the joint development of integrated and aligned roadmaps. Albright and Kappel, viewed roadmaps as forecasts of product family evolution over time, which were living documents. Although, they stressed the fact that a roadmap must be regularly reviewed and updated, a specific methodology for monitoring, reviewing and updating the roadmap was not provided. However, this roadmapping method is well fitted in the context of large corporations, which combine R&D and product development. It is a market needs driven approach based on closed innovation model (Albright & Kappel 2003). (Kappel 2001) also looked into the effectiveness of roadmapping and how this can be measured. He defined roadmaps as forecasts of what is possible or likely to happen, and as action plans. Figure 37 shows the main roadmap processes.

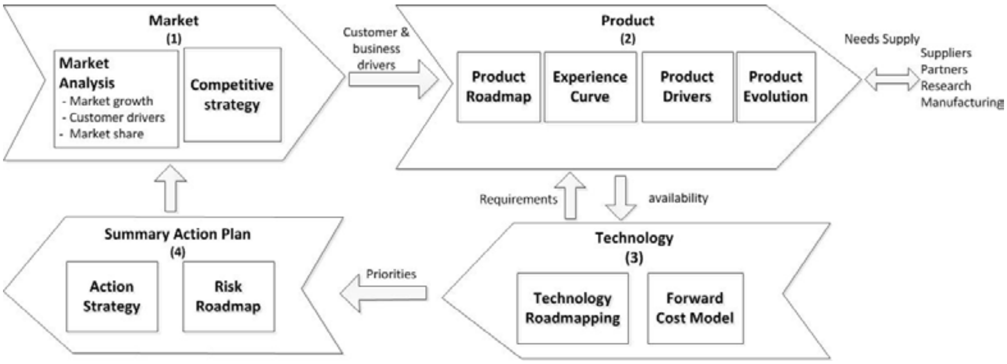

Figure 31: Lucent TRM company process. Figure based on (Albright & Kappel 2003), from figure 1, p.33.

Alignent –STAR

The Strategic Technology Roadmapping (STAR) Methodology was developed by Professor Nabil Gindy in collaboration with the Strategic Technology Alignment (STA) research group of the University of Nottingham as an integrated framework to help companies align their technology programmes with their business needs. This methodology is considered as a *3rd generation roadmapping (integrated technology management)*. It is a technology requirement planning process, which aims to assist the firms to integrate and align business, market, product, technology and research and development trajectories. In this framework, the firm aligns and links its R&D projects to its markets, products and business strategy. As a holistic planning process, it aims at generating robust R&D strategy and plans across the enterprise therefore, providing integrating technology management (Gindy et al. 2008), (Gindy et al. 2009). This approach is market driven and does not take into consideration socio-economic changes or other contextual drivers from the environment. Integration with foresight approaches is not provided. It is easier to be updated, since it is software based and digital. A process or plan for its updates was not provided though. Figure 38 below shows the main Roadmapping phases and processes.

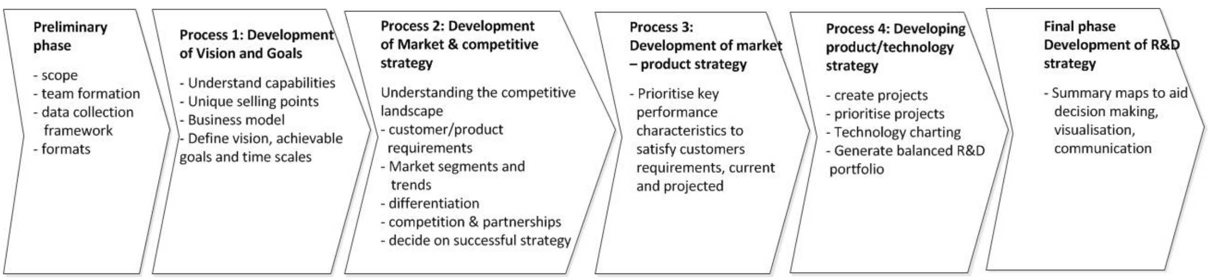

Figure 32. STAR processes. Figure based on *(Gindy et al. 2009)*

Alignent has developed a software called 'Vision Strategist and Vision reporter' for developing roadmaps based on STAR processes (Alignent n.d.).

Industry Canada

Industry roadmapping was used by Canadian Government since 1990s (Industry Canada 2007). They have sponsored several roadmaps in various industry sectors with the involvement of more than 1000 industry partners from more than 600 companies (Phaal, Farrukh, et al. 2011). Some examples are: Bio-based Feedstocks Roadmap; Clean Coal Technology Roadmap; Carbon Capture and Storage Roadmap; Electric Vehicles Technology Roadmap; Fuel Cell Commercialization Roadmap Update; IEA Technology Roadmap: Electric and Plug-in Hybrid Electric Vehicles IEA, Carbon Capture and Storage Technology Roadmap; Intelligent Buildings Technology Roadmap (PDF, 2 MB); Smart Grid Standards Roadmap; Sustainable Housing Technology Roadmap for Canada; Tailing Oil Sands Technology Development Roadmap; Wind Energy Technology Roadmap).

The roadmap of Industry Canada has *3 key phases: 1)* Recognition by industry sector firms that a problem exists and can be solved via roadmapping (development of vision and roadmap) *2)* Industry implement the technology roadmap. Roadmaps become the basis for cooperative research, development, and deployment activities which focus on new technologies and skills. *3)* The roadmap is periodically reviewed and updated.

Industry Canada is using the same processes framework as Sandia for developing the roadmaps. They have also provided a template for guidelines (see Table 6).

Introduction and background	• Mission and vision • Project objectives, goals, and intended results • Scope and boundary conditions of the roadmapping effort • The current industry: its products, customers, suppliers and manufacturing processes • Market trends and projections • Relevant constraint (regulatory, stakeholder, budget, etc.)
Technical needs and capabilities	• Targeted products • Functional and performance requirements • Current science and technology capabilities • Gaps and barriers • Development strategy and targets
Technology development strategy	• Evaluation and prioritization of technologies • Recommended technologies
Skills development strategy	• Evaluation of skills needs at present, and for recommended technologies • Recommended skills and program enhancements to affect those changes
Decision points and schedule	•Budget summary
Conclusion	• Recommendations • Implement recommendations
Appendices	• Roadmapping process • Participants

Table 6. Template for developing the roadmap source: Technology Roadmapping in Canada. A Development Guide adapted from (Industry Canada 2007).

METI-Strategic Technology Roadmap (METI-TRM), Japan (Government roadmapping)

The Ministry of Economy, Trade and Industry (METI) of Japan use technology roadmapping under its governmental innovation policy for promoting technology convergence and as a common "soft infrastructure" in order to facilitate a dialogue among academia, industry and government (Kajikawa et al. 2008), (Yasunaga et al. 2009). After the 1990s, known as the 'lost decade' in Japan's economy, METI's technology policy is focused more on basic and challenging technologies, rather than on applications related research. In addition, these technologies must be accompanied with clear future visions (Yasunaga et al. 2009).

METI defines *the objectives* of the Strategic Technology Roadmaps as follows:

1. "to enhance public understanding by providing an explanation of the perspectives, details, and future achievements of METI's (future & on-going) R&D investments with STR,
2. to help people in the R&D community understand future market trends, prioritize critical technology, and build "common understandings" for planning and implementing R&D projects, and
3. to promote cross-sector (academia-industry, among different industries, etc.) alliances, to stimulate interdisciplinary technology convergences and to call for coordinating other relevant policies" (Yasunaga et al. 2009).

METI's roadmaps are developed and visualised in three layers;

- *The top layer: "dissemination scenario"* shows the R&D pathways, the targets, and the relevant measures involved. It is a linchpin between R&D investments and Policy measures (e.g. economic instruments to implement Kyoto protocol). It initiates dialogue between policy makers and other government departments.

- *The second layer: "technology overview (technology map)"* is the only layer that does not have a time horizon. It provides an overview of technologies in each industrial technology field as a comprehensive technologies shop lists. These technologies are prioritise and discussed in relation to challenges and functions, which are needed to meet market and social needs.

- *The third layer: "technology roadmap"* uses the time axis to show performance and functional milestones and key technology areas supported by R&D.

Yasunaga, Director of NEDO (New Energy and Industrial Technology Development Organization), an R&D funding and project management organization, which also organizes task forces for developing roadmaps has identified 3 different types of roadmaps. These different types of roadmaps and their respective three layers are shown in Figure 39. Market-pull driven roadmaps are focused on incremental technological innovations and usually are top-down, from market to product to technology. Technology-push driven roadmaps are developed for industries in which the product dominant design is not yet defined and a mixture of top-down (from technology, to function, to value in the market) and bottom-up processes (from value, to function, to technology) are used. Social needs driven roadmaps are mainly top-down, but they differ from market-pull type of roadmaps in the sense that the new market is difficult to predict and a new "social framework" must be designed, as "society to be", before thinking about products and services.

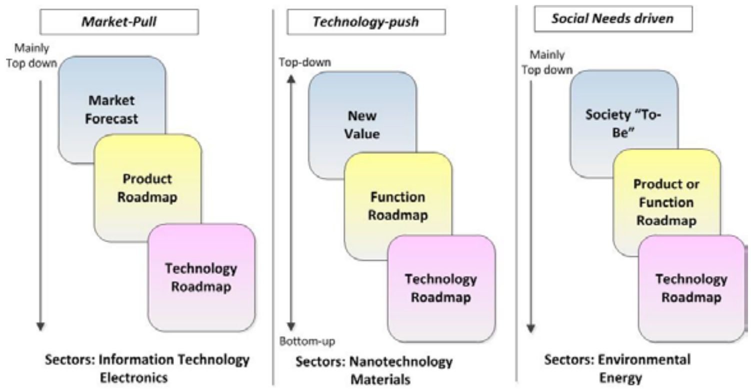

Figure 39. METI: Types of roadmaps based on NEDO experience. Adapted from (Yasunaga et al. 2009) from figure 5.3, p.69

This government approach to roadmapping has proven very beneficial in Japan in the sense that these roadmaps are used as "reference" scenarios and visions for private companies and universities and as discussion materials to formulate policy measures over time. METI is not interfering with the individual roadmaps developed by companies or by academia. In addition, although the developed roadmaps are updated every year, this reviewing is done in regular pre-set intervals and it is not dynamically triggered by changes in the roadmap drivers. The first roadmaps were published in 2005 involving more than 500 participants.

Kostoff & Schaller – ITRS roadmap

(Kostoff & Schaller 2001) have introduced *two fundamental approaches* for Roadmapping: a) *a workshop oriented expert-based approach* and b) a *computer based approach* (13). Their work focused on how Roadmapping can be used by industry sectors and national programs to support technological forecast. They analysed the application of the first sector level Roadmapping, *leading to the International Technology Roadmap for Semiconductors (ITRS)* (Schaller 2001). This Roadmapping activity presented a new approach, since it involved many organizations, with results open to the public domain. It aims at creating new industry standards for the sector. This was a milestone that promoted the approach to a much wider industrial, policy and academic community. The first ITRS roadmap was published in 1991 and was sponsored by the Semiconductor Industry in US (SIAM). It is currently sponsored along with SIA by the European Semiconductor Industry Association (ESIA), The Japan Electronics and Information Technology Industries (JEITA), the Korean Semiconductor Technology Industries Association (KSIA), the Taiwan Semiconductor Industry Association (TSIA). Similarly to Garcia and Bray, Kostoff & Schaller saw roadmapping as methodology that could also assist governments to plan and coordinate science and technology developments at international levels (Bray & Garcia 1997); (Kostoff & Schaller 2001). This type of approach is more fitted for incremental innovations and for well-established product-platform-technology designs. Both Garcia and Bray and Kostoff and Schaller stressed that more detailed description and guidelines of the approach are needed, in order to assist both companies and governments.

Disruptive roadmapping approaches

(Kostoff et al. 2004); (Linton & Walsh 2004); (Walsh 2004); (Vojak & Chambers 2004); (Linton 2004); (Galvin 2004); published papers on roadmapping methodologies for disruptive technologies. These types of roadmaps are considered as ***2nd generation roadmaps*** and a special issue was published in 2004 in "Technological Forecasting & Social Change, (Linton & Walsh 2004). Second generations roadmaps are analysed in more detail in section 2.3.9)

Kostoff & Simons

(Kostoff et al. 2004) published a milestone paper on 2004 on disruptive roadmaps. They integrated text mining literature techniques and roadmapping methodology (see Figure 40). The text mining technique was performed in order to identify both new potential technologies and experts associated to these technologies (see also related analysis in section 2.3.9). They also distinguished two approaches for developing disruptive innovation, a top-down and a bottom up. A top-down approach starts with the firm perceiving a market need and then tries to generate technology requirements, which lead to disruptive innovations. These innovations are first introduced to a niche market. A bottom-up approach starts with an evaluation of the firm's technological strengths and then the identification of potential products and services.

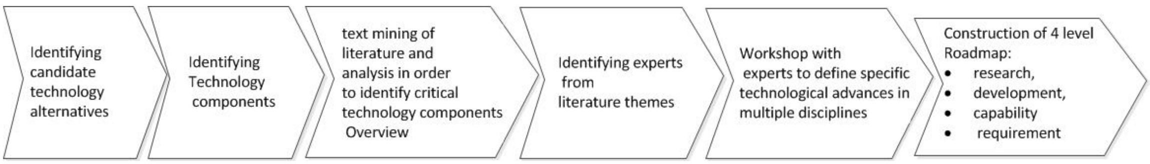

Figure 40: Disruptive roadmaps processes. Figure Modeled based on (Kostoff et al. 2004)

Walsh

Walsh focused on developing industrial disruptive technology roadmaps for micro technology and top-down nanotechnologies. He distinguished between emerging and disruptive technology roadmapping process. The main difference is that the emerging technology roadmaps focus on one emerging technology competing against one traditional technology, where disruptive technologies usually focus on a cluster of technologies competing against a variety of traditional technology solutions. He has offered a new approach for developing industrial technology roadmaps for disruptive technologies based on modification of Sandia's 3 phases approach. Please see Table 7 below that differentiate the two approaches (Walsh 2004).

Sandia Laboratories		**Walsh – Disruptive roadmaps**
Phase 1	Satisfy essential conditions	Satisfy essential conditions
	Provide leadership/sponsorship	Provide leadership/sponsorship from several multiple segments of value chain.
	Define the scope and boundaries of the technology roadmap	Define scope and boundaries
		Understand the nature of disruptive technologies
Phase 2	Identify the product that will be the focus of the roadmap	Identify promising "technology-product" paradigms
	Identify the critical requirements and	Develop "Holy Grail" Grand challenges

	their targets	
	Specify major technology areas	Identify and categorize major technology pathways
	Specify technology drivers and their targets	Specify relative technology infrastructure positions
	Identify technology alternatives and their timelines	Specify nomenclature and glossary activities, mini roadmap standards
	Recommend the technology that should be pursued	Identify specific technology segments for “mini roadmaps”
	Create the TRM report	Create ability for others to utilise output for their own roadmaps
		Create the TRM report
Phase 3	Critique and validate the roadmap	Critique and validate the technology roadmap
	Develop an implementation plan	Develop an implementation plan
		Review and update
		Seek transition timing to sustain roadmap

Table 7: A comparison between TRM phases based on Sandia (Bray & Garcia 1997) and on (Walsh 2004) *from Figure 8, p.181 .*

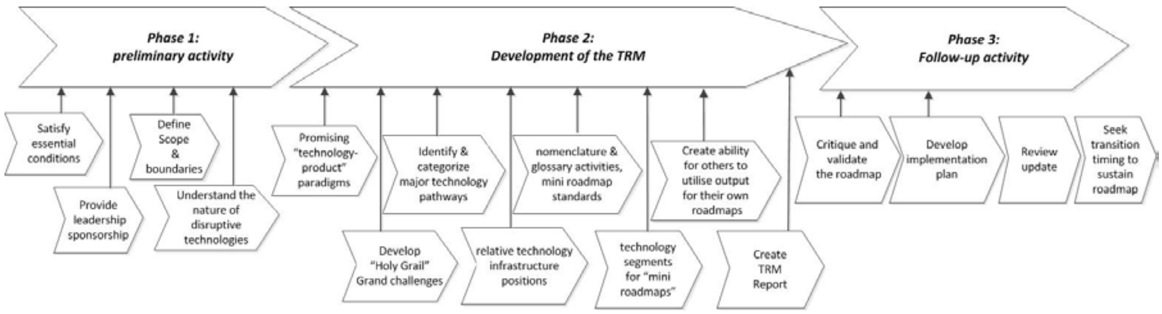

Figure 331:Walsh disruptive roadmaps phases, modeled based on (Walsh 2004) phases description, figure 8, p.181.

As we see in the above Table 7. Walsh specifies product paradigms instead of specific products. These product-paradigms are not referring to any specific product market. He also mentions ‘transition timing’ which is the time that a disruptive technology becomes the dominant design. In addition, this methodology focuses on developing disruptive industry roadmaps as mini segment roadmaps, which will be further developed by the industry players themselves. This case study was based on the effort of the International Industrial Microsystems and Top-Down Nano systems Roadmap (IIMTDNR), which numbered about 400 people, from almost same number companies, developed over a 5 year time. Although, Walsh case study offers guidance and insights on how to develop roadmaps for disruptive technology a detailed approach is not provided. He just mentions the complexity theory, the Delphi methods, text and data mining as promising techniques for the development of disruptive roadmaps. Instead, this case study highlighted the differences between these types of roadmaps and the roadmaps focused on incremental innovations. This type of methodology also preconditions the existence of industry consortia that can take up the roadmapping exercise, and although considered as needs driven, they are predominately technology push. It does not focus on commercialization of technologies or roadmap implementation. 'Dynamic Roadmapping' differs with this approach, since it is driven not only by technological changes, but also by complex socio-economic and other changes.

Vojak and Chambers

Vojak and Chambers (2004) stressed the importance of using the visionary insight of experienced technical managers and experts (for example via Delphi), together with approaches that assist these experts to identify complex patterns of change in order to anticipate technology disruptions. In their methodology, they have identified 5 components, which could cause possible disruptions at the subsystems level value chains: changes in standards, changes in architectures, integration and disintegration of elements, linkages across the super system and substitutions within the subsystem (SAILS). This methodology used a heuristic approach, which was based on observing past patterns of complex change across subsystem-level industries. The subsystem-level industries, that the study was focused on, were a) the frequency generation subsystems in wireless communication super systems; b) the optical multiplexing subsystems in optical communication super systems; and c) the high voltage electrical subsystems in automotive super systems. Vojak and Champers argues that linkages may result by changes in functionality in one system (either at super system level or subsystem level) that could cause changes in functionality in another system (either super system level or subsystem level). He gives an example of how the "increasing intelligence of test instrumentation has enabled increased functionality in the area of data handling. By providing database-like functions in the instrument itself, entire layers in the customer's information storage and handling chain can be eliminated with little additional development cost and essentially no added manufacturing cost. This can be very disruptive to suppliers at the next level in the chain" (Vojak & Chambers 2004). Similarly, in 'Dynamic Roadmapping', we need to take into account how changes that are introduced by the roadmap will affect the systems of suppliers, customers and intermediaries. 'Dynamic Roadmapping' thought, also considers changes deriving from socio-economic drivers rather than manufacturing and technology components. The authors did not offer a process model for their approach.

Linton

Linton developed a model for forecasting the profitability of innovations based on disruptive process technologies. The model forecast the market size for an early-stage emerging technology. Linton argues that for a firm to forecast an emerging technology involves tremendous corporate and personnel risks. His approach starts with the development of possible scenarios of the uncertain future. Then, the gaps related to supply/demand, pricing, profitability and value of intellectual property issues are identified and their impact on possible corporate strategies and government policies is explored. The application of this model was considered for nanotechnologies. A process model was not offered for their approach. It mostly aimed as guidance and as an analysis of benefits from applying the macro concepts of supply and demand in roadmapping process (Linton 2004).

Foresight and roadmapping

Saritas and Oner – Saritas & Aylen

Saritas and Oner suggest an ‘‘integrated management model’’ in order to support ‘‘multi-perspective thinking’’ by linking several dimensions of foresight with roadmapping. In particular, this approach integrates scenario methodologies in roadmapping and it was applied in the context of clean manufacturing at a European scale. Saritas and Oner argue that accuracy in planning for future innovations is improved by combining foresight and roadmapping methods. They also believe that this combination of futures techniques can offer clearer insights, especially in case of uncertainty, across a range of competing alternative technologies, or across broader social, political and economic outcomes. They argue that roadmapping pronominally focus on a single future, and it is considered as a useful tool for technology management, strategic and operational decision making and action planning. Integration with foresight techniques can support roadmapping by introducing “multiple futures” thinking, as well as help testing the roadmap’s robustness. In addition, they argued that scenarios, a foresight method, assume that the future is uncertain and thus, considers disruptive innovations. On the other hand, *scenarios do not provide pathways into the future, thus are not action oriented. Integration with Roadmapping will provide an actionable approach.* But, the authors acknowledge that even when scenario planning is used with Roadmapping, usually the roadmapping exercise follows a prior scenario planning exercise, meaning *scenarios have not been truly embedded in the roadmapping process* Saritas & Aylen 2010).

The authors suggest a methodology that uses scenarios at the *three phases* of the roadmapping process. *1) Before the roadmapping exercise.* These are baseline scenarios which are developed to capture the certainties and uncertainties related to the roadmapping issue. *2) During the roadmapping exercise.* These are alternative routes in the form of internally consistent narratives, or vignettes which can highlight “branch points” where one trajectory should be followed rather than another. They cover a narrow range of technical possibilities, and link them to specific markets. *3) After the roadmapping exercise.* These scenarios are used in order to provide an overview of the roadmap (linking all scenarios), in order to both develop an overall picture of the way ahead and test the robustness of roadmaps (Saritas & Aylen 2010) . Saritas & Aylen approach is focused on macro level R&D roadmapping.

Similarly, in ‘Dynamic Roadmapping’ model, scenario methodologies are used and integrated in the roadmapping process from the start. In the beginning of the roadmapping exercise, normative, visionary scenarios are used in order to set a high level vision and several goal oriented visions for the Roadmap. Then, exploratory, context scenarios are developed in order to understand the different plausible futures. These scenarios are developed after considering a set of identified PESTLE drivers, their likelihood to occur and their impact on the roadmap visions. The visions and initial roadmaps are tested using the context scenarios. In addition, the roadmaps, scenarios and visions are dynamically tested against conflicting social, economic, technical, political and environmental drivers and changes. An observatory provides alerts based on these PESTLE changes, in order provide information for updating the scenarios, visions, and roadmaps and change course of actions if needed.

McDowall and Eames

McDowall and Eames provided an extensive review of 40 studies, published between 1996 and 2004, on hydrogen futures, and they mapped the state of the art of scenario construction around hydrogen. They have identified *Six not entirely exclusive, types of methods: 1) Forecasts; 2) Exploratory Scenarios; 3) Technical Scenarios; 4) Visions; 5)Backcasts/Pathways; and, 6) Roadmaps.* The *exploratory scenarios* reviewed in the study, mainly explored longer-term (2030 – 2100) futures and included trend-breaking developments. Surprises were included only in 2 scenarios. The exploratory scenarios deemed as a good approach for thinking about drivers, although they were limited in emphasizing the drivers that operate at the 'landscape' level. They were also criticised as being an overly 'top-down' approach. The *Technical scenarios* were more specific than exploratory scenarios about the future systems, and their technical functionality. They were good in assessing the feasibility and desirability of alternative future systems, but did not included social and cultural dimensions in the analysis. Therefore future systems were viewed as a series of static technological options. Drivers of change have not been used to investigate the dynamics of the transitions to the modelled systems, or to explore factors that would promote or inhibit some futures developing. The *Visions* presented utopian descriptions of the future hydrogen economy, and they included surprises. They aimed in creating a shared picture of what the future could be. They were surprising similar in all studies and they also tended to gloss over areas of disagreements. Nevertheless, although visions were used, a clear desired picture of the Hydrogen future was not identified therefore, backcasting was rarely used. Roadmaps were not integrated with foresight approaches and assumed the desirability of hydrogen. Being also a normative approach they often defined a vision which was very vague and assumptions about the future were not made explicit. They assumed 'business as usual', based on continuation of current trends. The important merit of the roadmapping approach was the identification of barriers and solutions to them, as well as the generation of shared targets, but they missed factors driven by social values and policies on innovation. Most of these studies were top-down mainly focused on global and national drivers, and not on local drivers and opportunities. Each of these methods belonged to some foresight or roadmapping activity, but they were not integrated. As a result, expectations may remain on a utopian level and disagreements about visions were not addressed. In addition, when roadmapping was not involved, the results of foresight were not actionable. Thus, an integrated multi-method approach would be considered as more appropriate (McDowall & Eames 2006) .

Margherita Pagani

(Pagani 2009) described an approach for developing roadmaps for 3G mobile TV, based on a scenario evaluation and analysis through repeated cross impact handling. The scenario method was based on the main principles of system thinking and on the identification of multiple futures which were influenced by a number of interconnected factors. The probabilistic data was collected via interviews with 40 executives working for companies in wireless industry in companies in USA and Europe.

In this approach, the scenarios were assessed in each phase of the innovations value chain. This helped identify the most probable scenario for each actor in the innovation chain as well as the least favourable scenarios. For example, content providers were considered as the more sceptical players about the development of 3G value added services, while the network providers put their primary interest into the development of traffic to increase their profits, but the right mix of content is critical to the success of a mobile TV service. Emphasis was also put to forecasting the behaviour of the competitors. This method was used in order to develop multiple plausible future scenarios for the industry, while further data and ongoing development would provide an insight as to the likelihood of each scenario to be realised. In 'Dynamic Roadmapping' we are also taken into consideration the willingness of the innovation chain participants to participate in the roadmapping solutions. The approach that Pagani described focused predominantly on the foresight methodologies. Although possible roadmap scenarios were explored, a roadmap for each of these scenarios was not further developed, thus, the approach focused only on the foresight part.

Phase 1 — Detection of key factors a. Determination of the variables characterizing the system b. Division of variables into constant, predictable and uncertain factors c. Forecasting predictable factors along the temporal horizon d. Division of uncertain factors into independent and dependent e. Determination of simple events for each independent uncertain factor f. Decomposition into sub scenarios
Phase 2 — Foresight of alternative projections a. Experts' assessment of the marginal probabilities of events b. Assignment of compatibility levels between pairs of events belonging to the same scenario
Phase 3 — Calculation and formulation of scenarios a. Evaluation of sub scenario probabilities b. Choice of the most significant alternative sub scenarios c. Assignment of compatibility levels between pairs of sub scenarios d. Evaluation of scenario probabilities e. Clustering of similar scenarios
Phase 4 — Analysis, mapping and interpretation of scenarios. a. Evaluation of dependent factors b. Construction of complete scenarios using probabilistic scenarios, dependent factors, forecasts of predictable factors and constant factors c. Strategic analysis of complete scenarios

Table 8: Four phases of scenario approach source (Pagani 2009)

Gerdsri

Kocaoglu, Daim and Gerdsri are the research team from Portland State University, USA. They are working on roadmapping methodologies that utilise methods such technology development envelope (TDE), technology intelligence and the use of bibliometric in order to assist the information part in roadmap development (Gerdsri, Kongthon, et al. 2008).

Gerdsri argued that a systematic process to build and implement roadmaps has not been provided in the literature. He developed his own roadmapping model based on Technology Development Envelope approach, in order to strategically plan the research and development of emerging technologies in a firm. The model puts emphasis on the role of emerging technologies and how their evolution would significantly impact the company's strategic objectives. His approach was based on a combination of technology forecasting, identification, assessment, evaluations and selection. Delphi method and Hierarchical Decision Modeling (HDM) were the basis for building the Technology Development Envelope (Gerdsri 2005).

He developed a 6 steps approach (see Figure 42 below):

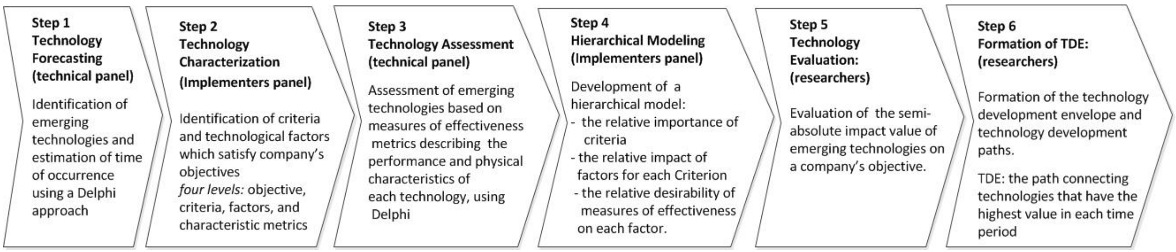

Figure 42: Developing a DTE for building emerging technologies roadmaps. Figure based on process description from (Gerdsri 2005), p.124.

This approach starts with the formation of two experts panels from technology experts and implementers (e.g. company's developers of products and services). These panels identify a set of criteria and the respective technological factors, associated with each criterion, which satisfy the company's objectives. The approach does not account for parallel development of technologies or their convergence, but deals with each individual technology instead. It does not take into account factors resulting from socio-political or economic changes, but rather focus on market and customer targets. Its application is envisioned at company levels.

Gerdsri also focused on the need to implement the roadmap and keep it alive. He also stressed the idea of keeping the roadmap up to date in order to reflect changes in its environment. Therefore, the organisation needs to be aware about when its roadmaps needs to be reviewed and updated in order to take the necessary actions to do so. Gerdsri proposed an approach to operationalize the review process of a roadmap, by assessing its current state. This approached is based on an evaluation model, which analyses the impact of changes in key roadmap drivers using a modified Analytical Hierarchy Process (AHP). The evaluation model then produces a signal about the current state of the roadmap, thus assisting the company's managers to take decisions about updating and revising it. One problem with this approach is that the drivers that the roadmap is evaluated against are the drivers that were thought of impacting the roadmap at the time they were identified. As the roadmap progress new drivers will emerge and some of the previous drivers will no longer be relevant. An observatory function that would constantly scan for new drivers, factors and signals would be a more holistic approach. Gerdsri approach is also based on experts' opinions. The problem with such an approach is that experts could be blinded by their own wishful expectations and by the street lamp syndrome, which means that they only can see changes in their immediate environments and areas of expertise (for example, technology changes within their field only). Therefore, this model cannot account for radical or disruptive changes, but it is very helpful for industries characterised by incremental innovations (Vatananan & Gerdsri 2011).

Gerdsri suggested an activity guideline for technology roadmapping implementation, and he also developed an action plan. This approach is taken into consideration change management methods which consider adoption of change within a company. It does not take into consideration changes, which need to be made in the supply chain, or changes that need to be coordinated among other intermediaries and customers (Gerdsri et al. 2010) .

Lee, Song and Park

Lee, Song and Park suggest a systematic roadmapping approach that *integrates a Bayesian network, scenario and roadmap methodologies* in order to allow a firm to assess the impact of future changes in its organisational plans. This approach is implemented in *3 steps: a)* defining a roadmap topology and the causal relationships via qualitative and quantitative modelling; *b)* assessing the impacts of future changes on organisational plans via current state analysis and sensitivity analysis; and *c)* managing plans and activities via development of plan assessment map and activity assessment map (see Figure 43). This approach was validated via a case study in of photovoltaic cell technology. In this approach, future changes and activities are modelled as random variables in order to explore the uncertainty. The Bayes' theorem is adopted to measure the ripple impacts at the system level. This approach is still on explorative stage and applied for company roadmaps and it was limited to only one technology (Lee et al. 2014) .

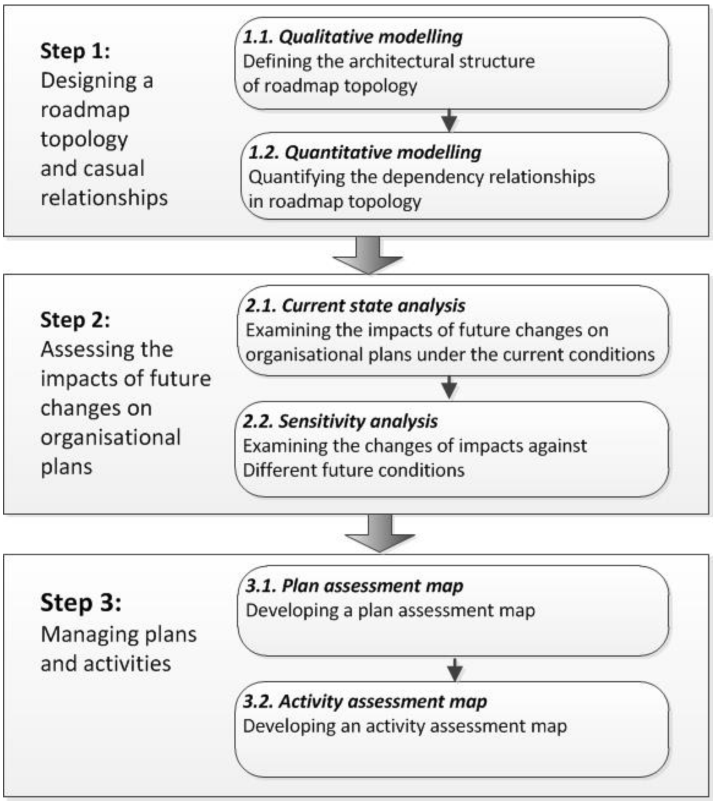

Figure 43: Lee and Park process framework. Based on *(Lee et al. 2014)*, adapted from Figure 2, p.5.

Recent approaches using data mining and bibliometric

Bibliometric approaches use statistical analysis, text and data mining techniques, patent analysis, citation analysis and terms analysis in order to analyse data from research performance perspective, and to identify new innovations via patents analysis (Daim et al. 2006), (Zhang et al. 2013).

VOSviewer (van Eck & Waltman 2010) is an example of a free software tool that uses probabilistic latent semantic analysis and text mining in order to automate term identification and visualization of bibliometric networks, which include journals, researchers, or individual publications. These networks are created based on co-citation, bibliographic coupling and co-authorships relations (van Eck & Waltman 2010).

These types of tools are started to be used in roadmapping approaches in order to cluster and visualise, terms, concepts, new technologies, research groups, and technology experts, etc. The idea behind this approach is that research papers or patents that get have many citations are signals of important changes and opportunities. Nate Silver in his book “The Signal and the Noise” (2012) tell us that we should be cautious of the “Big Data” trend and the use of statistical methods to extract meaningful conclusions. He references to the paper of John P. Ioannidis in 2005, which was titled “Why Most Published Research Findings are False”. Ioannidis studied positive findings related to medical research published in peer-reviewed journals. Later Bayer Laboratories tried themselves to replicate the experiments described in medical journals and they confirmed Ioannidis claims. They only could replicate only one third of the positive results published in the journals (Silver 2013).

Bibliometric provide some important intelligence as to where capacity is building, what is considered important by the academics and industry players and who is collaborating with whom. It can also help managers to identify and choose among the different options emerged from new technology developments, in research and patents, as well as to identify experts and build experts groups for their roadmapping workshops. Some examples of how bibliometric techniques have been used in roadmapping are provided by (Zhang et al. 2013), (Zhang et al. 2011); (Jin et al. 2015); (Huang et al. 2014)

Jin, Jeong and Yoon

Jin, Jeong and Yoon (Jin et al. 2015) argue that most roadmapping approaches are market-driven, while a technology push strategy is rarely used. They proposed a new methodological framework that is based on the collection and analysis of technological information in order to identify profitable markets and new product concepts. Their study uses two quality function deployment (QFD) matrices, the technology–product QFD and the product–market QFD, in order to develop the TRM and find new business opportunities. The approach was presented as a case study in the solar-lighting devices sector. They used data and text mining techniques in order to extract information from patents, manual handbooks and market reports and then map them in a roadmap. Reverse QFD is used in order to map the relationships among the identified technology keywords, between technologies and products and between products and market (consumers) needs.

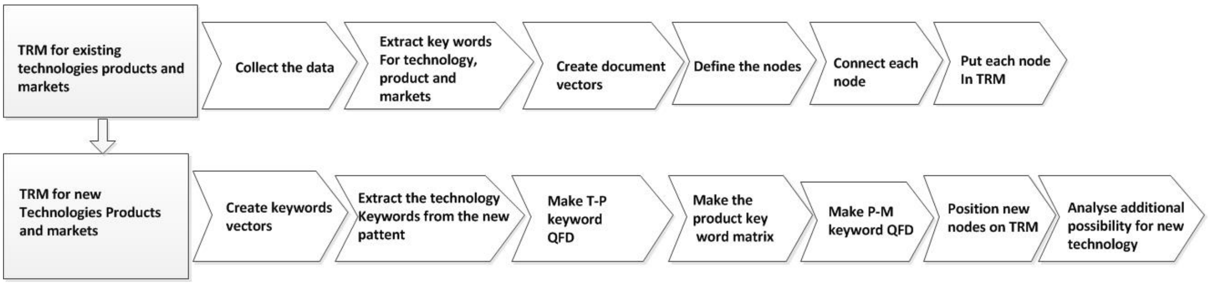

Figure 344: TRM processes using bibliometric. Figure based on (Jin et al. 2015) figure 1, p. 4.

This approach by Jin depends on relationships among existing technologies, products and markets, and preconditions that there is sufficient past information, which allows for extrapolation of trends in the future. In addition, experts' opinions are still needed in order to make sense and decide on the core keywords, their associations, and build the roadmap. Therefore it is a mixture of quantitative and qualitative methods. Also the case study used was an illustrative and not a real one (Jin et al. 2015).

Zhanga

Zhanga describe a similar TRM approach that combines bibliometric methods and the use of the text mining 'VantagePoint' software in order to extract 'core terms' and their relationships from science, technology and innovation databases (ST&I) and build a roadmap for electric vehicles. Their model is also a hybrid model, since it combines quantitative (bibliometric) and qualitative approaches (literature review, expert interviews and expert workshops). The produced roadmap is at a macro technology levels and it visualise the potential of emerging technology, incorporating market, the product and technique elements (Zhang et al. 2013). Their approach consists of 3 steps:

- *Step 1:* object definition: Use data mining techniques to retrieve core technology terms, both from scientific and research literature (fundamental research for e.g. Theories, concepts and algorithms) and from patents (technological innovations – inventions).
- *Step 2:* Define objects' relationships using the PCA (principal components analysis) method. The output is time-based and relationship based object-mappings.
- *Step 3:* constructing the technology roadmap: The previous object maps are explored by experts and put in timelines. This step is implemented in three parts.
  - o Use associated mapping to classify objects to related clusters.
  - o Define the phases of the technology development cycle along the ordinate axis of technology roadmap;
  - o Map the objects for technology roadmap and then place then in the roadmap XY axes (X: phases, Y: time).

A process model was not provided in their paper.

2.3.9 Roadmaps Generations

Tierney classifies the roadmaps evolution, as first and second generation. (Tierney et al., 2012)

First generations of roadmaps

First generation roadmaps (1970s- mid 1980s) are focused on *"accurate technology forecasting* (Gindy et al. 2009); (Bucher & Bucher 2003)*"* and on *"managing standard product continuous improvement efforts"* (Tierney et al. 2013). They have been used by both firms (micro level) and industries (macro level). These types of roadmaps imply a "*single root technology", strong technology trends, and a stable technology/product platform.* Incremental advancements of a specific technology are the driving factor for developing such roadmaps. The main focus is on creating improved, cheaper and better product/technology paradigms. The *International Technology Roadmap for Semiconductors (SIA)* (Semiconductor Industry Association 2011); (Lipscomb et al. 2008) is a representative example, during which an industry roadmap was developed in order to set industry standards. In this roadmap, a *single cell technology* (e.g. transistor), a *stable process product platform* (e.g. MOS & Bipolar) and an *established technology process base* (e.g. semiconductor micro-fabrication) are given at the outset. The firms in the semiconductor electronics industry are developing their own roadmaps based on SIA roadmap. The SIA roadmap is based on the "Moore's Law" forecast, which says that the number of semiconductor devices per chip would double every two years; The Industry of the Future's aluminium industry roadmap is another type of first generation roadmaps Aluminium Industry Technology Roadmap (Fernández-Dávila et al. 2011). These types of roadmaps are applied in less complex domains, where a single technology is the predominant factor of the innovation design and the nature of innovations are linear and incremental. Technology life cycles are used as a base for forecasting technology development in the roadmap. Thus, these innovations are mapped along *a single critical technology pathway* over time. They intend to be used as a *common vision* for the entire industry, for its evolution, as well as a platform in order to create *industry standards*. The key contribution of first generation roadmaps to roadmapping is the *generic roadmapping graphical structure* (see Figure 25). 1st generation roadmaps were dealing only with incremental innovations.

Emergent technology roadmaps of sustainable technologies are also classified under this first generation. The difference with product technology roadmaps is that the emergent roadmaps are *not driven by a strong product market focus, but rather of product platform focus.* Usually, emergent roadmaps are *driven by one new* or *emerging technology*, which is assessed against traditional technologies. They focuses on forecasting potential opportunities driven by the new or emerging technology; the competitive position of a firm in relation to the technology; and how both the emerging technology and the company's competitive position will develop (Garcia & Bray 1997). *Data mining and text mining* are key methods in identifying emergent technologies, while experts are also usually used for analysing their potential. *S-Curves* are used as a method to forecast and understand the evolution of the emergent technology trajectories and the innovation milestones (Walsh 2004).

For first generation of roadmaps the main assumption is *that past performance and trends will indicate future performance*, assuming a stable and *deterministic future* for the firms and industry (Vojak & Chambers 2004).

Second generation of roadmaps

2nd generation roadmaps (mid 1980s- end 1990s) set out to *improve strategic technology planning decisions* (Gindy et al. 2009) (Bucher & Bucher 2003) and to *"explore the disruptive potential of emerging technologies"* (Tierney et al. 2013) in order to illustrate its value for companies and industries. ***These are emerging disruptive roadmaps.*** These type of roadmaps, by contrast to first generation roadmaps, *do not have a single cell technology* to advance or *"fixed market targets or a stable product process paradigm"*, but are *"still generated from a single root technology"*, therefore, they do not address innovations stemming from complimentary or convergent technologies (Tierney et al. 2013). They are used for either a) *product placement*, in terms of identifying changes in the current process product platform; or for b) *identifying potential applications enabled by emerging technologies*, when a clear understanding of how these technologies are related to actual products is missing. Mostly they serve as a method to map technology developments on several critical dimensions, they use multiple technologies lifecycles, but still, they do not address "multiple root technologies, constraints from drivers other than market drivers or new business models" (Tierney et al. 2013). TEL innovations, for example, are facing many other constrains, stemming from socio-political and economic drivers (e.g., increased unemployment of young people, changing nature of jobs, global pressures for cheaper and faster education, etc.). *The strong importance of PESTLE drivers is a key distinction between 2nd and 3rd roadmaps generations*.

According to (Walsh 2004) the most fundamental distinction between emerging and disruptive roadmaps is that the emerging technology roadmap (of 1st generation) focuses on a single technology competing against a single traditional technology, where disruptive technologies tend to be a cluster of technologies competing against a variety of traditional technology solutions. Furthermore, in most cases these new sets of technologies will aim to "creatively destroy existing technology product market paradigms" (Walsh 2004).

Main examples of such roadmaps are Nanotechnologies roadmaps (Walsh et al. 2005), (Linton & Walsh 2004); The extensive use of market and technology drivers, technologies life-cycles and assessment of technologies readiness are emphasised in the roadmapping methodology (Tierney et al. 2013). These types of roadmaps are developed also at both company and industry levels.

Figure 45 shows the multiple technology life cycles: Emerging disruptive technologies versus more traditional options.

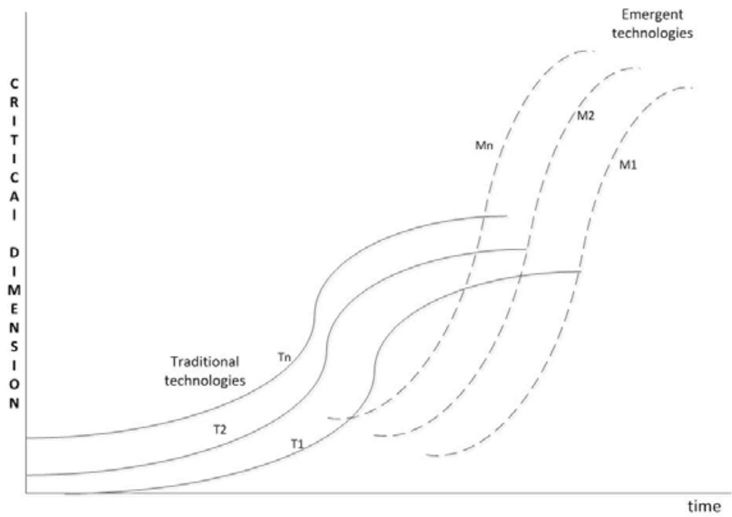

Figure 45: Technology transitions from traditional to emergent technologies. Figure adapted from *(Tierney et al. 2013)* from figure 2, p.198.

Some successful examples of using emerging technology drivers to understand possible disruptions in the roadmaps, as well as to analyse new opportunities for the development of products or services are based on *bibliometric methods*, such as text mining of literature and scientific papers, data mining or similar data analytics techniques (Zhang et al. 2013), (Zhang et al. 2011), (Jin et al. 2015), (Huang et al. 2014). In these cases, an integration of foresight and roadmapping is *only done at micro technology levels* with limited plan for strategic implementation. *Delphi foresight method* is also used in order to identify and assess the impact of potential disruptive technologies (Linstone & Turoff 2002), (Cuhls 2001).

Some researchers (Phaal, O'Sullivan, et al. 2011), (Tierney et al. 2013) have used technologies lifecycles to map emerging technology innovations. (Walsh 2004); (Kassicieh et al. 2002); (Tierney et al. 2013) and (Kostoff et al. 2004) have recognised the need to identify potential disruptive innovations based on disruptive technologies and created a second generation of disruptive roadmaps.

Kostoff provided a *systemic approach* for identifying potential disruptive technologies. *First,* he used literature-based discovery process and text mining to identify potential disruptive technologies, their components, and experts. *Then,* experts were used in order to identify possible component alternatives based on the previously done literature review and prioritise them. Roadmapping workshops (with experts identified from the mining activities) were organised in order to develop an implementation roadmap. However, his view of disruptive innovation is of "introduction of products and services that are dramatically cheaper, better, and more convenient", which would provide radical improvements as compared to the current offerings (Kostoff et al. 2004). He recognised the importance of many insights needed in order to foreseen the potential of the disruptive technologies and the strong technology push that is driving these types of roadmaps. However, these types of innovations *are more in line with radical rather than disruptive innovations*. In addition, a very detailed roadmap at this very fuzzy front end of disruptive technologies would not be effective, due to the uncertain nature of the technology developments, and their adoption.

(Walsh 2004) provided an enhanced approach to the first generation roadmaps for the *nanotechnology and pharmaceutical industries*. He also provided a comparison between incremental and disruptive roadmapping methodologies using the emerging microsystems and top-down Nano systems industry as a case study. In this case study he notes that: "A disruptive technology industry roadmap and its processes differ from sustaining roadmaps, emergent technology roadmaps, and roadmaps focused on firm, national, or regional interests. A firm-based roadmap, for example, is based on the firm's competency or market interests. … Finally, it differs from a national or regional roadmap set for disruptive technologies, since they artificially limit the scope of the technology and market focus of a disruptive technology base." Walsh summarised some key differentiations between disruptive and first generation roadmaps: disruptive technology roadmaps *have numerous technology pathways*, which *compete with numerous traditional technology solutions* in the marketplace, and *many levels of commercial and technological infrastructure*; for each emerging portfolio, competing and/or complementary manufacturing technology bases exist; there are *limited number of dominant designs*; *limited number of standards in the industry*; potential *applications span over a large number of industrial settings*; a *terminology taxonomy* will become the first standard in the industry; experienced managers will be needed to *re-direct the commercial focus* of existing firms.

Usually, firms are reluctant to adopt the disruptive innovations, as they are in competition with their own start-ups: new value propositions of the innovative firms will change radically the existing product/technology platforms and industry targets. In terms of roadmapping, (Walsh 2004) stressed that: a separation and selection of important elements that would assist the disruptive technologies to mature must be done. A separation should also be done among the markets in which the disruptive technology could be a technological substitute for the industry, and those in which, disruptive technologies can start completely new industries. The aim of disruptive roadmaps was to support the company's management and staff to better understand the industry, the markets and their evolution. The main aim is to provide guidance to the industry stakeholders including technologists and investors as well as entrepreneurs in conceptualizing and understand the value of disruptive technology, but it was left to the companies, regions and individuals to develop their own individual roadmaps, based on this guidance, which would suit their own interests and needs (Walsh 2004). Thus, we can classify this type of roadmapping as a macro level innovation policy and industry roadmapping.

This is a fundamental difference with the 'meso-level 'Dynamic Roadmapping'' framework developed in this PhD, which aims to assist the roadmap participants to produce common roadmaps, and also implement them, monitor them and adapt them. Additionally, in Walsh case, he focused more at radical changes of superior quality technological innovations that *resemble more of discontinuous, rather than inferior quality disruptive innovations*. Therefore, it is difficult to consider these types of roadmaps as disruptive, since by definition (Christensen & Raynor 2003) disruptive innovations start with inferior quality innovations when compared to existing offerings. Therefore, we can conclude that a methodology for creating disruptive roadmaps is still a research gap. Nevertheless, both Kostoff and Walsh have identified the need for a more holistic approach that would address the integrality nature of the technological innovations, the many uncertainties involved, as well as the multi-organisational involvement in their successful adoption and implementation.

(Linstone 2004) recognised the need to involve technology foresight, both normative and exploratory approaches, together with computer simulations in order to better understand changes that might lead to disruptive innovations. He did not though provide a detailed approach. He recognised that disruptive innovations might be triggered and/or influenced by external contextual (e.g. economic, social, technical) factors. To this end, disruptive innovations might not be commercialised and scale *unless other co-innovators develop complementary technologies and suppliers, intermediaries and customers are all benefited by the promise of the disruptive innovations.* Thus, a roadmap based only on market driven demands focused on contemporary customers' needs *without taking into consideration the PESTLE drivers*, the respective supply and adoption innovation chains and their drivers will not be successful.

Third Generation of Roadmaps

3rd Generation of Roadmaps (end-1990s – today), are focused on *integrated technology management* (Gindy et al. 2009) (Bucher & Bucher 2003) where *roadmapping is integrated in the business processes of the companies* and it is still in the development process. According to R. Tierney, pharmaceutical innovation roadmaps are good examples of this type. (Tierney et al. 2013) argues that a 3rd generation roadmapping approach needs to be developed due to the changing nature of innovations. *Innovations today are shaped by many drivers, while the ways that technologies are used is changing and new business models are required.* In addition, such innovations can usually *cause radical strategic changes* in the industry and companies. Understanding the nature of these innovations is very important in order to develop 3rd generation roadmaps (see also analysis of different types of innovation in section 2.2.1). The authors consider pharmaceutical innovations as very good example of such type of roadmaps, since they require the development of *a number of different root technologies* that need to be developed *along multiple dimensions (CDs – critical dimension pathways)* and the results needs to be *seamlessly integrated* (Tierney et al. 2013). Tierney and his colleagues have identified 6 main differences that such innovations are differ from the innovations managed by the previous roadmaps generations. "First, these innovations are created at the interface of multiple root technologies. Second, these innovations often do not benefit from a unit cell such as the transistor does for the semiconductor roadmaps. Third, differing applications drive innovations that will require differing and often multiple critical dimension development for each technology being utilized. Fourth, the boundary conditions constraining today's innovations and products are much stricter than ever before. Fifth, drivers are much more important to these new innovations. Sixth, new business models such as focused consortia are driving technological development without benefit of predetermined architecturally stable product process platforms" (Tierney et al. 2013) .

In addition, lack of historical data related to radical, emerging or converging technologies necessitates the use of both quantitative and qualitative methods (Stummer & Heidenberger 2003). Overall, making predictions about the kinds of technologies that will best meet the future needs of diverse types of stakeholders (suppliers, developers, users, adopters, and intermediaries) is very challenging, because there are so many ways for technology predictions to go wrong and because one single company will not have the resources to develop such innovations. Therefore, ***a meso level type or roadmapping***, where consortia of innovators are working together to develop the innovations are necessary in order to combine the resources required and share the risks involved. Moreover, the new innovations are often happening on *the interfaces of more than one technology*, when technologies are *combined or converge*, rather than on linear development of each technology individually. This calls for new ways of thinking about the future, including how to: take advantage of different perspectives, look at technology from different planning horizons, think through discontinuous, non-linear effects, use technology strategy tools, leverage both formal and informal strategy-making processes and consider risk profiles. Planning the future requires a common agreement that can only be effectively achieved through the mobilisation and engagement of all stakeholders towards this direction.

(Tierney et al. 2013) provided a 3rd generation roadmapping approach for Pharmaceutical industry. Their approach combined a) surveys with 40 professionals in order to identify pharmaceutical landscape drivers, and b) primary and secondary research to identify already existing consortia for specific innovations. For example literature review was used in order to identify a list of pharmaceutical components based on the new technology subsets explored by the current consortia, while questionnaires and technology life cycles were used in order to assess the progression of new set of technologies. This approach, although recognises the need to use an extensive set of drivers to understand the changes that drive the disruptive innovations, and the need to use consortia for the development of the innovations, the produced roadmap only provided a holistic picture of the evolution of the industry, emphasising foresight rather than implementation thus, it was done at a macro rather than meso level. A detailed description of the approach was not provided, and the roadmapping exercise stopped before its implementation or update. The assumption behind its implementation was that the already existing consortia would take up the roadmap under consideration when developing their own innovation approaches. In the case of the 'Dynamic Roadmapping' the co-innovation consortia are formed in order to develop their roadmap for themselves to implement and monitor/update.

Moreover, many originally very promising technologies run into a "last mile" problem, essentially failing to convince the wide majority of users of their benefits. The issue of uncertainties in user responses and acceptance of emerging technologies *are often ignored, and in reality the future visions simply concentrate on technological potential and supplier's deployment processes.*

2.4 Need for a systemic approach to innovation management approaches

The picture today has not changed significantly since popper's survey in 2008, regarding the practice of TFA methods, although, the current volatile environments, the convergence in technologies and domains, and the increased impact of socio-economic changes in innovations, clearly demand for new approaches of using and combining FTAs (Tierney et al. 2013), (Bainbridge 2009), (Porter et al. 2004) (Georghiou & Cassingena Harper 2013), (Kaivo-oja 2011). The innovation policy set out by government actions since the 1980s, mainly have been focused on funding Research and Development, as well as Research Networking activities among firms, research institutions and small and medium enterprises (SMEs). An observed gap is the lack of governmental funding, at both national and EU levels, *to support long term coordination around missions and visions* that would lead to desired change with important socio-economic impact (Georghiou & Cassingena Harper 2013). In addition, FTA methods have often suffered from the technology bias, favouring technology solutions, which are lying within the comfort zone of the scientific community, or they have been addressing incremental changes in well-structured domains. Horizon scanning has also remained a problem. Even in the few cases that this method was used, the topics monitored were looked in isolation without consideration of their cross-impact effects. Weak signals that would influence these topics and would make an impact have not been well addressed or assessed since today. Failing to foresee the recent economic crisis in Europe and US was also another disappointment of TFA effectiveness. On the other hand, the big uncertainties of our times, the rapid social changes and the economic instability are forcing EU and European governments to *shift their focus to grand and societal challenges* (e.g. health, energy, climate, education, unemployment, etc.) and wishing to link them to strategic research. These challenges have already become part of the ERA and Horizon 2020 debates. *The big challenge with such future innovations is that they are discontinuous and/or disruptive* to the current institutional and governance structures. Think for example about the challenge of 'creative classroom' for schools, set by the Education and Culture Directorate and how this was hindered by issues, such as fixed curricula heavily controlled by governments, banning mobile devices at schools, and heavy regulation in assessment methods, and in time and space of studies (Saritas 2011).

(Saritas 2011) describes that the new challenges in the 2000s demand for **a systemic approach** to foresight. These challenges and complexities have to do with social and economic instability, hostility due to economic downturn, and lack of resources, such as drinkable water, food, and energy supply and other environmental factors, such as climate change, regional conflicts, and respective population movements. In addition, the world is becoming increasingly interconnected and interdependent due to globalization and advances in internet, data technologies and mobile communications. This global context is changing very rapidly due to technology changes (and their convergence) in information technologies, bio technologies, fuel cells and nanotechnologies. At the same time information technologies, including social media, provide individuals freedom of expression, opportunities to develop global ventures and demands for more equality in social settings. Like (Georghiou & Cassingena Harper 2013), (Saritas 2011) claims that although changes in social and economic contexts demand for new systemic methods, foresight has remained largely unchanged. Moreover, he argues that, any "systemic" approaches to foresight, in order to address the complexity involved in the PESTLE challenges will require open human and social systems. Due to the unpredictable nature and behaviour of such open systems, a comprehensive "understanding" of the systems is needed as a starting phase. A systemic foresight approach would also require the wider participation of diverse types of stakeholders not restricted to the opinions of technical experts, but rather for "increased inclusivity across all areas of policy making. This is in line with two of 'Dynamic Roadmapping'principles (see Dynamic Roadmapping Principles Chapter 3, pp. 127, 128): a) bring the whole system in a room, which means, bringing together all necessary stakeholders who are necessary in order to envision, plan and implement these changes (systemic innovations) and b) Construct cartography of the domain in the very start of the process in order to get a good understanding of the systemic relationships involved, any including tensions, issues and other factors that can influence the system.

(Saritas 2011) identifies three important drivers for the development of systemic foresight methods:

- "The need to gain a rich understanding of existing systems and procedures, their history and possible futures
- The analysis of different stakeholder perspectives and their social relations in the system, which can affect and be affected by the process
- The impacts of formal and informal networks and procedures, which can be in favour or in conflict with other systems" (Saritas 2011, p9).

(Könnölä 2007) also points out the linkage of foresight methods and systemic innovation. He tell us that "at the implementation phase foresight often assist with an enhanced responsiveness of the system and new policy configurations, leading thus to change in attitudes towards the future such as embedding long-term thinking in decision making processes, raising overall awareness of challenges and opportunities, and the development of a foresight and learning culture."

(Georghiou & Cassingena Harper 2013) identify three main factions of FTA approaches today: a) identification of a challenge, b) articulation of a challenge at a general level and c) helping to achieve what is variously called orchestration or alignment of actors around the challenge. Set up of observatories and continuous Horizon scanning are becoming very important methods, which should aim for holistic rather than atomistic information. (Webster 2002) bring our attention to the fact that just only duplicating Horizon scanning activities of the big companies is not an efficient approach to foresight. He argues that "The most intelligent foresight is that which has best intelligence of the configuration of relationships between companies, professionals, existing and potential markets and so on" (Webster 2002, p.156). Therefore, an observatory function should be combined with methodologies such as scenario and weak signals analysis, via the construction of cartographies of the domain controversies in order to identify, map and manage disagreements and tensions. This is in line with the 'Dynamic Roadmapping' *principle: that an observatory function will provide means to continuously test and update the roadmaps.* Georgiou points out that "There is a need to assembling plausible narratives, overarching themes and clusters rather than lists and to develop commensurate abilities to perceive interconnectedness" (Georghiou & Cassingena Harper 2013). There is also a trend to move from just identification of emergent technologies and their classification according to some themes, to a more issue-oriented foresight approach. In addition, policy based decisions are no longer based only on research and science, but on successive stages of both formal and informal consultations and dialogues as well as different expert's advice, which involves many different types of stakeholders. They are also expressed in multifaceted and relevant, long-term oriented, facts and visions (Langenhove 2002).

In 'Dynamic Roadmapping', conceptual modelling is used in order to capture the positions of different innovative communities in the domain and identify and model their tensions, visions, and motives. Therefore, 'Dynamic Roadmapping' is very relevant today. It advocates an approach to manage systemic innovations via co-innovation stakeholders' value networks, an observatory and integration of foresight and roadmapping approaches. *Context scenarios* are used as a method to test how robust the visions and strategies (action plans) of the roadmap are, when they played out in the scenarios' plausible futures. This testing has two dimensions: a) how effective the roadmapping visions are. This means, are we aiming at the right goals, targets? (The 'why' part of the roadmap). And b) how efficient our action plans are. Are we planning the right processes, resources, technology developments to achieve these goals? (This represents the 'how' operational part of the roadmap). In addition, contexts scenarios help us to position our roadmaps and contextualise our visions in different local, regional, sectorial, economic, political situations. Finally, combined with *weak signal analysis* and *trends analysis*, helps us to choose and plan for the migration path that is derived from the most likely/ most high impact scenario, according to current analysis of information, and update it later, as more information are becoming available. An *observatory function* makes sure that new developments are identified and their impact is analysed on the cartography, the roadmaps and the directions of the possible futures.

2.5 Literature Review Conclusions: Reflections on 'Dynamic Roadmapping' conceptual model for systemic innovations

This section summarises the conclusions from the literature review as gaps in roadmapping methodologies and it shows how these gaps have been addressed by the 'Dynamic Roadmapping' model.

2.5.1 FTA methods gap: Integration of foresight and roadmapping approaches and the need for an observatory in order to keep the process agile.

As derived from literature review, a more holistic approach that would integrate foresight and roadmapping is needed for creating 3rd generation roadmaps and managing systemic innovations. Foresight approaches identify changes in PESTLE drivers that might drive opportunities for systemic innovations. They also provide a good understanding of how such changes could impact (either as possible threats or opportunities) a future vision for systemic change. Literature and practice shows that although foresight, technology intelligence and roadmapping methods are widely used, there is very limited integration between these approaches at their process levels (Porter et al. 2004), (Lichtenthaler 2007), (Ilevbare et al. 2014).

Foresight is used as a tool for policy development in order to identify plausible future developments, driving forces, emerging technologies, trends, threats and opportunities, which relate to the broader socio-techno-economic environment. These different outlooks on possible future developments are usually presented as stories in the format of context scenarios. In foresight, plausible context scenarios (whether desired or not) may be used to monitor complex and dynamic environments (Strauss & Radnor 2004), (Porter et al. 2004).

Roadmapping is used to integrate "business strategy, product development, technology and R&D activities and actions" (Vatananan & Gerdsri 2011) and usually "advocate" the selection "of particular technical solutions" (Saritas & Aylen 2010). The majority of more recent technology roadmaps have been driven by customers' needs, linked to specific market opportunities, products, technologies, resources, capabilities, strategies and policies ((Behrendt et al. 2007), (Strauss & Radnor 2004), (Vatananan & Gerdsri 2011); (Pagani 2009), (Drew 2006), (Ilevbare et al. 2014).

Both approaches foresight and roadmapping have limitations when implemented alone.

Limitations in foresight methodology

Foresight methodologies provide a good understanding of the possible technology paths and the associated drivers, whether economical, business, legal, environmental or social, but they often lack both the active formulation of new ideas and their subsequent exploitation at operational levels. Often, they remain in the form of reference documents or guidelines, sometimes resulting in the development of new industry standards, or helping to formulate actions to be included in European and other national and regional funding programmes. In the educational domain, the EQF (European Qualification Framework) is such an example, which, although developed at EU policy levels, has so far never had significant adoption by European Higher Education Institutions.

A gap in foresight research and practice exists in terms of how to translate future changes into operational decisions and actionable plans. This gap causes difficulties in consensus-building in planning at operational stages, which has a potential for actionable implementation (Lee et al. 2014). It is widely recognizable that such applications of foresight are challenging, for several reasons:

- The actual multidimensional characteristics and complex nature of the foresight exercise. In general, and especially in volatile environments, people tend to prioritize and react to pressing issues and threats, rather than make decisions and take actions related to weak signals and uncertain future drivers (Loveridge 2001) cited by (Saritas & Oner 2004).
- Future changes can impact decisions not only related to technology developments, but also in other strategic interrelated activities driven by social, political, legal and business drivers. Therefore, a change in one area may also trigger changes in other areas, thus affecting the effectiveness of the current and projected strategic goals and operational tasks (Lee et al. 2014).
- It is very difficult to assess the impact of future changes presented in possible future scenarios and incorporate them in decisions and actions at organisational planning and operational levels. Even when different paths are visualised and a roadmap is defined for each path, there is no pragmatic approach, which would inform decision making in an organisation as to when and how to adjust its roadmaps (Saritas & Oner 2004), (Lee et al. 2014).

- The lack or very little integration between the three main technology intelligences usually involved in foresight exercises, i.e., monitoring, forecasting and assessment. Rather than a planning stage foresight snapshot, a more holistic view is needed in order to provide a continuous process that integrates the different technology intelligence processes, especially in cases of radical technological change taking place in a volatile environment (Lichtenthaler 2007).

An innovation management framework, which would provide a coordinated planning at operational levels, and involve all the necessary actors (value network) necessary in order to achieve consensus and realize the foresight targets is currently lacking. On the other hand, this kind of strategic planning, which integrates technology drivers with business planning, both at strategic directions and at detailed implementation tasks, is widely used in roadmapping processes, especially in company roadmapping.

Limitations in Roadmapping methods

Roadmapping has great merit as an approach in establishing shared targets, and concrete goals, identifying obstacles and planning solutions to overcome these obstacles. In addition, the roadmapping plans and actions, as outputs, provide a good way to measure progress, while they are implemented. Roadmapping is also very successful in integrating market drivers and technology trends in strategic planning (McDowall & Eames 2006). The problem is that it usually only focuses on *specific technical solutions* (Saritas & Aylen 2010), which are predominately driven by customer needs linked to specific market opportunities, products, technologies, resources capabilities, strategies and policies (Lorenz & Siegfried 2006), (Saritas & Aylen 2010), (Strauss & Radnor 2004), (Vatananan & Gerdsri 2011), (Pagani 2009); (Drew 2006), (De Smedt et al. 2013).

Therefore, Roadmaps have been criticized for lacking analysis of socio-economic trends and social requirements, activities which are core to foresight methodologies, hence roadmapping methodologies are *not usually connected to social contexts* (Carlsen et al. 2010). Ilevbare et al. examined 650 published roadmaps reports and carried in-depth interviews with Roadmapping practitioners and concluded that there is an obvious lack of focus on risk and uncertainty in the roadmapping methodologies today (Ilevbare et al. 2014). Although roadmaps clearly define and link the steps needed for developing innovations, they are *weak on dealing with surprises* and external changes stemming from socio-economic, political, social changes (De Smedt et al. 2013), they have been characterised as linear and isolated (Saritas & Aylen 2010) and *look at futures driven only by technical feasibility* (Saritas & Aylen 2010). The risks and uncertainties associated with PESTLE drivers, which are embedded in the presented Roadmap pathways are not identified and assessed in the roadmapping process (Kajikawa et al. 2011) instead, *a straight line - projection or a single scenario* is assumed (Pagani 2009) without making assumptions about the future explicit (Strauss & Radnor 2004). As suggested by Margherita Pagani “roadmapping incorporates in fact technology trajectories and competitive environment inputs and it assumes a straight-line projection or single scenario”, which implies a linear approach to innovation. “In general, assumptions about the future are not made explicit or explored, leaving ‘business as usual’, or the continuation of current trends as a default perspective. Consequently, the future is treated instrumentally, as a ‘policy problem’, with the emphasis placed on what is to be achieved" (Pagani 2009). (McDowall & Eames 2006), (Lee et al. 2010) also state the lack of integration of roadmaps and scenario planning.

The need to integrate Roadmapping and Foresight approaches

Although an integration of roadmapping and foresight approaches at process levels would be very beneficial in providing this innovation management framework, literature shows that such integration is very limited. For example, *an integration of scenario –based foresight approaches and roadmapping* will use scenario planning in order to capture the full contexts of decisions and the anticipated future changes and technology roadmapping in order to provide innovation management at strategic, and detailed actionable tasks levels (Lee et al. 2010), (Lee et al. 2014), (De Smedt et al. 2013).

It is possible to find few examples in literature of similar efforts to integrate scenario planning and roadmapping in order to capture the different possible future contexts. (Saritas & Aylen 2010) integrates scenarios and PESTLE drivers' methods with roadmapping. (Pagani 2009) incorporates scenario planning and cross-impact analysis in order to assess the possibilities of the different scenarios. (Strauss & Radnor 2004) use multi-scenario roadmapping to extend the single scenario roadmap based on the process and architectural formats of the roadmap. (Suharto 2013a) adopts multi-scenario based roadmaps and Bayesian causal maps for cross impact analysis of volatile markets. (Lee et al. 2010) have proposed the operationalization of a multi-scenario roadmap based on a Bayesian belief network approach. (Robinson & Propp 2008) introduce multi-mapping scenarios in their roadmapping methodology and described the need for analysis of the innovation chains in the roadmap's solutions. But he did not provided a detailed approach. (Ilevbare et al. 2010) integrate scenario planning, roadmapping, and options thinking. But, all these cases are again limited to the company level (Strauss & Radnor 2004), (Vatananan & Gerdsri 2011), (Drew 2006).

Furthermore, roadmapping and scenario planning *are usually kept separate*, with scenario planning done in the beginning at corporate planning levels and roadmapping done afterwards by operational managers and R&D personnel (Saritas & Aylen 2010) (Strauss & Radnor 2004).

In the 'Dynamic Roadmapping' approach, roadmapping and scenario planning are integrated throughout the roadmapping process, with each alternately feeding forward and back to the other. This is essential if the roadmap is to be able to adapt to changing circumstances and hence remain relevant as a tool for coordinating the co-innovators continuing efforts. In addition, while these approaches are good examples of using scenario-based approaches in future planning methodologies, they remain on conceptual levels, since they mostly focus on an analysis of the future changes and their impact. As (Lee et al. 2014) discuss, we still miss the link between future changes and organisational plans, which causes difficulties in consensus-building in planning and operational stages.

Some successful examples of using emerging technology drivers to understand possible disruptions in the roadmaps, as well as to analyse new opportunities for the development of products or services, are based on *bibliometric methods*, such as text mining of literature and scientific papers, data mining or similar data analytics techniques (Xin Li et al. 2013), (Xianjun Li et al. 2013), (Huang et al. 2014), (Robinson et al. 2013). Yet again, in these cases, the integration of foresight and roadmapping is only done at micro-technology levels, with limited planning for strategic implementation. In addition, the wider contexts, and the PESTLE drivers are usually ignored.

(Phaal, O'Sullivan, et al. 2011) and (Wurtz et al. 2013) have used technology lifecycles in order to map emerging technology innovations. (Walsh 2004), (Kassicieh et al. 2002), (Tierney et al. 2013), (Kostoff et al. 2004) all recognised the need to identify potential disruptive innovations based on emerging technologies and created a second generation of disruptive roadmaps. But as it was analysed in the previous section 2.3.9, they aimed more at radical changes of superior quality technological innovations, which could not be characterised as disruptive innovations. In (Christensen & Raynor 2003) model, disruptive innovations always start with inferior quality products or services compared to the current offerings. The combination of an innovative business model coupled with an emerging technology with significant development potential, means that the products and/or services rapidly move upmarket, disrupting existing incumbents, while enhancing the quality of existing technologies, which he refers to as sustaining technologies, as they enable existing incumbents to maintain their current market position. They also point out that a disruptive innovation needs to be able to adapt and change rather than follow a rigid plan. It is also noted that an over detailed roadmap could be disastrous for systemic as well as disruptive innovations, since they are both discontinuous in nature and the research, as well as the visions of the stakeholders, can originally only be focused on the fuzzy front end with the details of product and market uncertain (Yu & Hang 2010).

But, whether disruptive or sustaining innovations, it is evident that there is a need for a more holistic approach that addresses the integral nature of innovations, and their plausible emerging contexts (Phaal, O'Sullivan, et al. 2011). Therefore, it is argued that roadmaps should not only address the evolution of their markets, products, services and technologies, but take account and be continuously adaptive to their wider changing contexts, and, critically, be created and agreed on by the stakeholder networks that are necessary to the successful implementation of the innovation.

In conclusion, even when an integration of foresight and roadmapping methods is achieved, it is usually done only at the *micro company level*: (Strauss & Radnor 2004), (Suharto 2013a), (Vatananan & Gerdsri 2013), or *at macro policy/industry level*: (Phaal, O'Sullivan, et al. 2011) technology intensive product sectors; (Tierney et al. 2013) Pharmaceutical; (Walsh 2004) nanotechnologies; (Saritas & Aylen 2010) metal processing industry; (Xin Li et al. 2013) Photovoltaic Industry; (Pagani 2009) 3G mobile TV; (Zhang et al. 2011) electric vehicle. Moreover, such attempts at Marco approaches still remains at conceptual level with no practical implementation (Ilevbare et al. 2010) and not at a meso level of multi-organisational networks of stakeholders. These networks are becoming increasingly common, when implementing larger scale systemic innovations, where multiple players all need to co-ordinate their activities over a period of time for the innovation to succeed.

In some cases roadmapping methods have been integrated with scenario planning at sector or industry level but it is usually done only in mature sales industries (Pagani 2009) (Walsh 2004) and not in complex and multi-disciplinary environments such as education and training. Moreover**,** there is no detailed information on *the types of stakeholders* that need to be involved or on *the ways stakeholders and experts may be engaged* in either foresight or roadmapping processes (Pagani 2009), (Saritas & Aylen 2010), (Strauss & Radnor 2004), (Porter et al. 2004).

Need to differentiate between normative and exploratory scenario

In addition, (Könnölä 2007) tells us that foresight projects reports have emphasized the importance of developing and *agreeing on a common vision* (normative approach to scenario planning), which would provide the synchronization of the innovation system. Therefore, the emphasis on "foresight activities has tended to shift from positivist and rationalist technology-focused approaches towards the recognition of broader concerns that encompass the entire innovation system (Könnölä 2007)" including its environmental, social and economic dimensions .

Although roadmapping "is a normative and goal oriented method" (Saritas & Aylen 2010), often *there is no clear differentiation* from most of the authors *between the development of desired scenarios (illustration of desired future visions) and exploratory or forecasting scenarios (based on current trends and signal projections)*. When developing the desired futures and visions in a roadmap, either at company, or product levels, usually a top-down approach is used which takes into account only the commercial perspectives and strong trends, such as the market and customer drivers as well as the organization's strategy (Cho 2013). At sector levels, the vision is often vaguely defined, if at all, with the emphasis on the steps needed to achieve broad targets, such as to: generate standards for the industry; identify investment opportunities for R&D based on a selection of promising technologies, or identify changes in the current process product platform. Usually, *exploratory scenarios* (Schwartz 1995), (Wilson & Ralston 2006) are the only type of scenarios developed, when foresight and roadmapping methodologies are integrated. The exploratory scenarios are describing alternative, often competing futures, based on PESTLE drivers and an early warnings analysis, and can provide a measurement, as to which future is most likely to be realised based on monitoring of these PESTLE drivers. A limitation of this approach is that visionary elements of the scenario are missing. Moreover, as the company's aims and strategy are often a given at the start, the purpose of the scenarios is to test and refine the strategy. "The double uncertainty approach diminishes the contribution of scenarios by not including visionary paths among the plausible paths into the future" (Bezold 2010). Only the paths linked to uncertainties, that we can see or project are identified. *Visionary scenarios*, on the other hand, can be used to indicate the path to take and reveal stakeholders' motives, plans and our assumptions for what is desirable in the future. As such, they can also be used for negotiating common perspectives and manage disagreements among the stakeholders (Porter et al. 2004). However, although visionary scenarios are very good at guiding long term systemic change and innovations, they are weak on specifying clear goals and targets dealing with future uncertainties and hence, may be derailed by changes in their operating context (De Smedt et al. 2013). *An interaction of both Exploratory (can be) and normative (ought to be) scenarios is necessary* in order to a) aim for a desirable systemic change *(should be)* and b) make sure that we can understand the threats and opportunities within the possible futures *(can be)*.

The ‘Dynamic Roadmapping’ model differentiates between “desired” scenarios and “context” scenarios. Desired scenarios are stories that articulate visions of desired futures (what we want to happen, the goals we want to reach). They are used in order to articulate and externalize the visions of all actors involved in the co-innovation system, reveal their underlying assumptions and to create an initial draft roadmap. The *scenario intuitive approach* is used in order to generate “Context scenarios”, which are stories of possible futures in the operating context, based on foresight analysis of the field, answering the question “what could happen if…” The initial draft roadmap is then ‘stress-tested’ by placing it in each of the projected context scenarios and refined with possible alternative pathways.

The need for an observatory function in order to keep the roadmapping process alive

As analysed above, it is important to integrate foresight methods such as scenario planning methodologies into the Roadmapping process, in order to provide an understanding of possible changes and their foreseeable influences and impact on the strategic plans and specific solutions identified in the roadmap. This continuous adaption and monitoring of the roadmap’s context is required in order for it to enable successful long-term adoption (Vatananan & Gerdsri 2013), (Gerdsri et al. 2009), (Yoon et al. 2008), (Strauss & Radnor 2004), (Kostoff & Schaller 2001).

Dynamic Roadmapping therefore argues that in order to keep any developed roadmap dynamic and agile, the roadmap’s key drivers, uncertainty dimensions and assumptions need to be fed into an ***observatory function*** that supports the roadmapping implementation and update process. It uses these to scan for relevant developments in the wider contexts in which the roadmap is operating, which it feeds back to the co-innovation roadmapping group. Thus, the ‘co-innovation’ roadmapping group should regularly monitor the uncertainties associated with future forecasts, trends and signals identified in its foresight projections by continuously checking these against current realities, so that it can review and update its roadmaps, context scenarios, its targets and even its desired future, as necessary.

2.5.2 The meso–level gap: Multi-organisational roadmapping to deal with systemic innovations

The need to bridge long term research with short and midterm implementation

Literature review shows a shift towards more short term strategies. In today’s volatile environments, forces like the current economic crisis, the internet, the mobile and social network revolutions, lowered barriers to entry, and globalization have made the markets less defined, while customers and competitors are becoming more and more unpredictable. Rita Gunther McGrath argues that “In a world where a competitive advantage often evaporates in less than a year, companies can't afford to spend months at a time crafting a single long-term strategy. To stay ahead, they need to constantly start new strategic initiatives, building and exploiting many transient competitive advantages at once. Though individually temporary, these advantages, as a portfolio, can keep companies in the lead over the long run” (Gunther McGrath 2013). Therefore, we see a tension among the long term visions developed in foresight projects and short-term strategic planning in operational levels of the firms. As analysed before, lack of long term research strategy targeting more basic technologies can hurt an industry's competitiveness in the long term. New methodologies to evaluate business opportunities, and approaches to innovation are needed. Such approaches will provide a combination of investment both in long-term, basic and challenging technologies, which are based on a common visionary framework that could produce many opportunities for innovation, and in short-term portfolios of many flexible competitive advantages.

To combine both approaches, policy makers need to share the financial risks with industry players and research institutes for investments in new and challenging technologies, while, an integrated network of all necessary stakeholders needs to be mobilised in order to plan, coordinate and implement a number of innovations in the short and mid-term. As argued in section 2.3.9, ***meso-level roadmapping*** is needed not only to overcome both the linear thinking implicit in the previous generations of roadmaps and the challenges associated with the demanding nature of systemic innovations, but also to bridge in both directions between long term research and short and medium term application based innovations.

Consequently, innovation models and policy development need to move from linear to iterative, adaptive systemic innovation practices and from traditional forecasting methods to "participatory and systemic foresight" and roadmapping approaches (Koivisto et al. 2009). In the *co-innovation 'Dynamic Roadmapping'* approach, we are moving from purely push-driven "positive technology focused approaches" to more systemic innovation processes that involve the entire innovation system. These approaches integrate PESTLE drivers (Political, Economic, Social, Technical, Legal, and Environmental) and foresight perspectives, together with a pull-driven co-development of user requirements, in order to generate new value opportunities. These in turn are then translated into continuous, adaptive strategic planning and implementation at domain, business and operational levels.

Foresight in this respect is a sense making process which identifies and manages uncertainties and their potential impact on the roadmapping strategic and operational choices. This perspective of managing future uncertainty and strategic planning at operational levels is necessary when dealing with innovations in complex and volatile environments. Furthermore, this *cause and effect analysis* for managing uncertainties needs to be *continuous throughout the roadmapping implementation*, in order to gain continuous insights about future events that could affect (impact) the strategic directions and or the expected outcomes of the roadmap. This monitoring enables better informed decisions, planning and coordination of roadmap changes, whether strategic in nature *(increasing effectiveness)* or operational *(increasing operational efficiency).*

One example of Policy gone wrong is the lack of supply of computer programmers in UK. UK universities have made a shift in curricula requirements of Information Systems and Computer Science from programming to learning to use close to market applications and devices. This was in part due to pressures from the leading companies in the market (Microsoft, apple, etc.) in the market that wanted graduates closer to their job requirements and in part due to the recent generation of plethora of devices (e.g. smartphones, tablets), which focus on development and content consumption by people. Raspberry Pi founder Eben Upton, speaking at Wired 2013. Upton (2013) in his speech at the Wired (2013) stressed the fact that this direction shift deprived universities (e.g. Cambridge) of supply of computer programmers. He said that "We have a generation of consumers not producers, and consumption hardware and not production hardware…We are trying to generate a group of people who see computing as an open environment, see it as a platform for creating their own destiny (Solon 2013). To solve this problem, Upton developed Raspberry Pi. It is a credit card size single board computers that costs from $25 to $35 which allows people to experiment with hardware and learn how to program. This is a nice example of how academia, researchers and industry have collaborated to solve the problem. Wired 2013 video: Eben Upton (Bhartiya 2013).

The widely used ***Future Search approach*** (Weisbord & Janoff 2010) was adopted and adapted in 'Dynamic Roadmapping', which has been developed with the goal of bringing diverse, and often conflicting, parties to an agreed way forward on a common significant issue. The key principle of this approach is to *get the whole system in the room*. This approach seek to bring together all the key players necessary, all of whom are working with a common aim to bring about an agreed set of changes, but who are mutually dependent in various ways in order to achieve their respective goals. However Future Search has generally been used to resolve a particular "stuck issue", which those involved, once agreed on their desired future, can then move forward and address their issue in the short term. In the case of meso-level roadmapping, however, we are creating at least midterm and often long term future plans are created, so uncertainties in the operating environment take on greater significance. Therefore *scenario planning* was adopted, as developed by Shell and SRI, to deal with this turbulence.

2.5.3 Organisation and management Gap: The need to integrate Top down and Bottom up approaches to roadmapping

These approaches have to do mainly with the formation and engagement of the roadmapping groups and to some extent the subsequent management of the roadmapping process.

The Invited or Top-Down Approach: The top-down 'invited' approach presupposes a leading agency or organisation that is recognised in the field and is prepared to form the roadmapping group. The lead can be from the 'push' side, typically a company, but could be a funding agency, with a programme that is developing an innovative product, service or a combination, which they wish to mainstream. *Potential difficulties* with the invited approach might be: a) the '*distance from the ground'* (e.g. focus only on recycling current technological solutions) b) include the *'usual suspects'* in the roadmapping group (e.g. people who have been invited for consultation before and c) achieve a *forced consensus* (over glossing utopias) avoiding tensions and conflicting ideas. A bandwagon effect can take place when trying to reach consensus driven either from majority or the dominant views of the group leader, strong experts, etc. Other challenges associated with this approach include convincing the roadmapping participants to leave their normal work and participate in the roadmapping events, as well as funding their expenses for their participation.

The Emergent or Bottom-Up Approach: The emergent approach requires many people to put forward what they are interested in and then to discover like-minded partners and update or form new co-innovation groups. Following up their shared interests (e.g. through online discussions, or a cartography map of the domain), they begin to form roadmapping groups, which, if it strengthens and gets enough momentum, will agree to start on the roadmapping process and meet face-to-face. This approach clearly avoids the 'distance from the ground' problem, but may face a 'completeness' problem of bringing together the required range of stakeholders necessary to succeed. An additional risk is that like-minded networks would not challenge their beliefs or mental models and they will use their collaboration as a way to reinforce them. But whether emergent or directed, effective innovation in a complex domain requires bringing together all the required stakeholders who, if not actively participating, are likely to cause the adoption of the innovation to be blocked. Therefore, it is important to combine top-down with the bottom-up approach via the creation of a cartography map for the domain. In both the top-down and bottom-up approaches it is difficult to bring all the required stakeholders together, so both may use aspects of the other to attract further stakeholders.

Figure 46 shows the classification of the different future planning initiatives based on the type of methodology used (foresight or roadmapping) and the management of the process (top-down or bottom-up). It is noted here that most roadmapping activity includes some element of foresight, but usually limited to technology trends, while foresight is usually used to inform some development processes, but often it is an independent activity. Here they have been separated in order to classify typical approaches and illustrate how the 'Dynamic Roadmapping' model has drawn from each of these approaches. Typically, foresight approaches focus on *improving understanding of change drivers and developing policy and research agendas,* while roadmapping approaches mostly focus *on operational plans and innovation management*. Top-down approaches focus on *consensus building,* while bottom-up approaches focus on *diversity and exploring a range of possibilities* through the identification of different value networks, which have common goals. Based on the analysis above, future planning projects are classified with respect to the different methodology (foresight or roadmapping) and the approach used (top-down or bottom-up). Each quadrant identifies the key dimensions of future planning approaches based on this classification. In the 'Dynamic Roadmapping' methodology elements of all four types have been combined, thus integrating foresight with roadmapping, using both top-down and bottom-up approaches.

The aim was to support and strengthen networks of people that are connected by shared objects (what they investigate, produce, e.g. learning technology specifications, tools, applications, best practices, training, etc.) through activities.

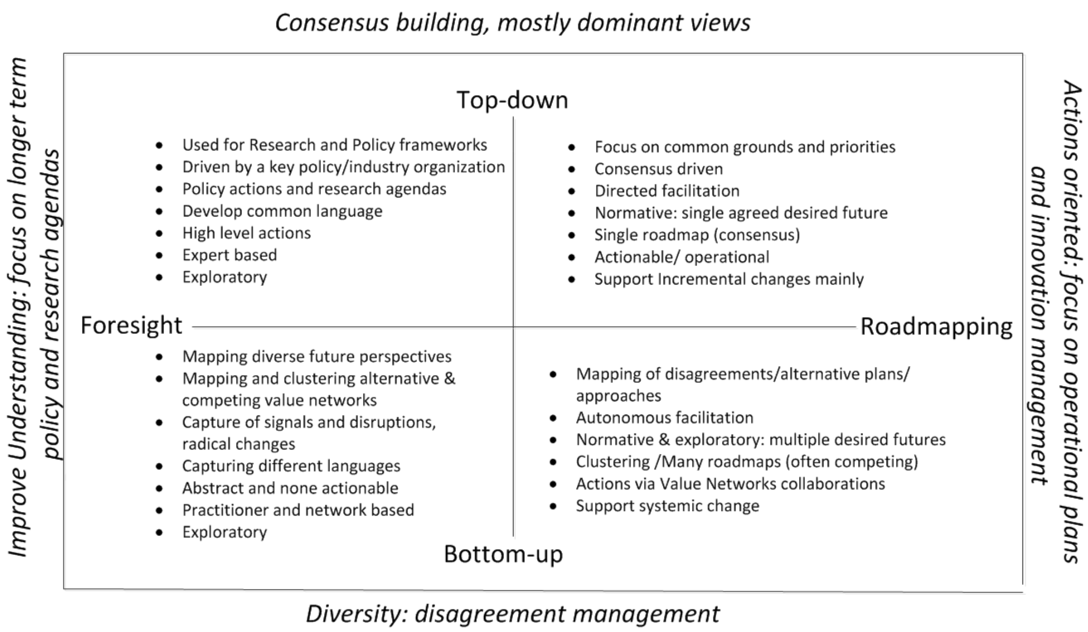

Figure 46. Classification of future planning initiatives based on literature review

2.5.4 Adoption Gap: Lack of integration of Roadmapping and change management

As demonstrated in literature review, the actual implementation of the roadmap plans and their adoption potential is always a big challenge. *Ron Adner in his book* (Adner 2012) proposes a useful model for innovation adoption and change management (see section 2.27 pp.63-66), which has been adopted and adapted in 'Dynamic Roadmapping' (see also section 6.6.5: workshop 5). Essentially he points to the dependencies an innovator will often have on co-innovators and also the value chain suppliers and intermediaries. In those terms, an innovation, to succeed, will require significant changes to an interrelated set of other subsystems of the eco-system. He suggests mapping out these players and their interdependencies in a ***'value blueprint'***. The key questions are a) who else has to co-innovate with you to complement and complete your value proposition? And b) who else needs to be able to adopt your value proposition in order for it to reach the end customer/users?

An important difference between Adner's approach and the 'Dynamic Roadmapping' is that Adner, similarly to Moore's model, appears to be primarily focused on the supply side, with the final end user or customer placed at the end of the chain, but not involved in the co-innovation process. This is an oversimplified model and in reality, it is the interplay with users and other intermediaries that place an important role in the development and evolvement of innovations (Carlsen et al. 2010), (Tuomi 2004), (Tuomi 2002). In addition, 'end users' in systemic innovations are considered as more complex, with multiple decision makers involved (e.g. in TEL this may involve ministries and departments of education, agencies, heads of schools, teachers, parents and learners), each of whom have a key role to play in the co-innovation. The whole functional and innovations chains of supply/product/service/delivery may have to change, and an agreement of various actors might needed in order to implement the new innovations. Again in TEL example, these may include suppliers, producers, distributors, value-added resellers, content developers and providers, curriculum and examination boards, who may be considered as intermediaries, and education authority decision makers at national, regional and local levels, as well as educators and learners who can be considered an extended set of End Users/Customers. Figure 47 shows arrows from the 'End User/Customer' back to the Co-Innovators to indicate this involvement where, for simplicity, 'End User/Customer' is taken to include all those involved in purchase or adoption decision-making.

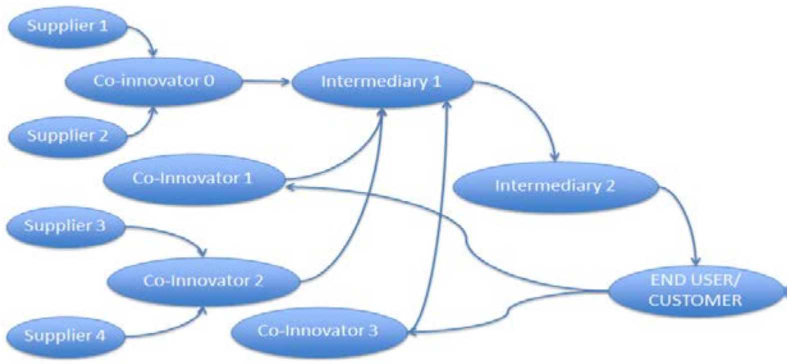

Figure 47: Value Blueprint. Figure adapted from (Adner 2012) from figure 4.1, p.87.

(Kaivo-oja 2011) in his eBook agrees that this *linear thinking of traditional supply chain management is not adequate when managing systemic innovations*. He argues that "a very strong link between foresight and change management in order to promote more efficient systemic innovation processes" is needed in order to integrate "both supply and demand side thinking" (Kaivo-oja 2011) and also account for the social changes that can re-shape the innovations. Such a framework combines foresight, operational planning and change management. Therefore, a good understanding is needed of the distribution of uncertainties across different partners and other actors (e.g. adopters of the innovation) involved in realizing the value propositions and functional jobs of the roadmap in different social contexts. Similarly individual companies are no longer able to manage entire value chains internally. Typically, both roadmapping and systemic innovation involve a lot of coordination of tacit knowledge, informal communication, and disagreement management, making the whole process a learning process.

Chapter 3: 'Dynamic Roadmapping' Conceptual Model and Framework

The previous chapter 2 provided an analysis about the gaps that the 'Dynamic Roadmapping' model is addressing in existing roadmapping methodologies. This chapter provides the connection between the *model's methodology and the theory that grounds this research work.*

There is a distinction between the *'conceptual model'* of the '*Dynamic Roadmapping'* and its process *framework* (methods, process, implementation steps, and templates). This chapter, first provides the theoretical underpins and grounding of the *conceptual model* as an abstract meta-model, which describes the methodologies used, the theories behind these methodologies, why these theories were chosen, which interactions have been supported (sections 3.1). The rest of the chapter (sections 3.2, 3.3, 3.4) describes the model and its process framework. The framework is focused on the actual processes, which take place in 'Dynamic Roadmapping'. These selected processes are derived and supported by the meta-model. So the framework can be seen as the *practical part* (presented and validated via a case study in Chapter 6). In terms of what kind of processes, steps, templates, and guidelines are needed in order to implement the 'Dynamic Roadmapping' model and how to organise this in a case study that supports TEL innovations at European schools. A detailed actionable implementation and analysis of the Dynamic Roadmapping process is an important contribution to advance both the theory and practice of 3rd generation roadmaps. As demonstrated by literature review, there is a lack of methodologies and detailed processes for developing such types of roadmaps.

Dynamic Roadmapping' Principles

Dynamic Roadmapping meets the need for innovation models and policy methods to move from linear traditional forecasting and roadmapping methods towards more iterative, integrative, participatory and holistic systemic approaches to innovation. 'Dynamic Roadmapping' has been developed as a new **meso-level**, multi-organizational approach to roadmapping. It sets out a new 'dynamic', 'adaptive' or 'agile' approach to innovation management, designed to enable multiple co-innovators to form **co-innovation roadmapping groups** in order to strategically plan and coordinate their efforts to bring systemic innovations through to the point of adoption and mainstreaming.

The 'Dynamic Roadmapping' model is based on the following principles.

The 'Dynamic Roadmapping' process

- is a social, dynamic, intelligence gathering and analysis process, which is used in order to create meaningful current and future models of the domain in question, based on which, we justify effective actions, which leads to effective systemic change. Therefore, it constitutes a *dynamic knowledge creation process* for the involved innovative communities.

- Constructs a *continuous cartography* of the domain which maps the various innovative communities, their interests, motives, and tensions, agreements and disagreements, as well as the trends and signals associated with PESTLE drivers.

- Has the power to *produce systemic innovations* and also extend and transform the involved communities' practices, processes and cultures.

- Brings *the whole system in a room* as a 'Co-Innovation Group', which means, bringing together all necessary stakeholders who are necessary in order to envision, plan and implement systemic innovations. as a co-innovation group,

- Develops *a high level vision for systemic change* which is then contextualised in different national, regional and European levels, as well as in different business, social and political contexts.

- Tells us *"where do we want to go?", "where are we now and where do we come from?", "what changes are emerging that can help or hinder our root?"*

- Provides mechanisms to the innovative communities (co-innovation group) *to monitor and timely update* their roadmaps.

- Has chances to be *adopted and implemented* after the roadmap is created, thus producing sustaining innovations e.g. "who else needs to be aligned with the roadmapping visions and actions in order to achieve successful implementation?"

3.1 Theoretical Grounding of the 'Dynamic Roadmapping' model

The 'Dynamic Roadmapping' concept and practice is built on two learning models that both emphasise dynamic knowledge creation as a social learning process: *the SECI model of knowledge creation* developed by Nonaka and Takeuchi (Nonaka & Takeuchi 1995b), (Nonaka et al. 2000) and the third generation of *Historical Cultural Activity Theory - CHAT* further developed by Engeström (Engeström 2001), (Engeström 1999) .

Moreover, it integrates processes from foresight, Future Search, roadmapping and change management: i.e., conceptual modelling used as a means for disagreement management in order to capture, negotiate, and extend the knowledge and foresight of the targeted stakeholders, and their communities; foresight methods (including Context scenario planning, PESTLE and weak signal analysis) are used in order to monitor and contextualise the roadmapping desired futures and planned actions; The Future Search [2] approach is used in order to provide a historical analysis of the innovative communities activity systems and innovation milestones, as well as in order to articulate their shared desired futures; and a 'meso' level Roadmapping methodology, which employs a 'co-innovation' value network of stakeholders, who form a community of practice and agree to build a roadmap based on their desired futures and to coordinate the tasks needed for its implementation.

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[2] *The Search Conference*, Merrelyn Emery & Ronald Purser, Jossey Bass, 1996, *Future Search*, Marvin Weisboard & Sandra Janoff, Berrett-Koehler, 2000

3.1.1 Roadmapping as a knowledge creation process with emphasis on disagreement management: Combining SECI and CHAT

The 'Dynamic Roadmapping' approach uses the SECI model of knowledge creation as a conceptual model for building, adopting and monitoring roadmaps aiming to manage systemic innovations at meso multi-organizational levels. The *Historical Cultural Activity Theory - CHAT* is also applied in order to understand what drives the knowledge creation among the innovative communities.

SECI and CHAT, complementary or conflicting models?

SECI and CHAT although at first may seem contradictory or at least having different scopes, they are used as complementary approaches in 'Dynamic Roadmapping' methodology. Engestrom himself acknowledged the usefulness of the SECI model for accounting the importance of tacit knowledge in dynamic knowledge creation process (Engeström 2008), (Engeström & Sannino 2012). Further he states that "The two theories do not have to be seen as mutually exclusive or hostile. Nonaka and Takeuchi's emphasis on the alternative modes of representing knowledge and the transitions between them offers important insights that may be overlooked within the theory of expansive learning. On the other hand, the theory of expansive learning, based on the dialectics of ascending from the abstract to the concrete, offers a new framework for analysing the interplay of the object under construction, the mediating artefacts, and the different perspectives of the participants in a progression of collectively achieved actions" (Engeström 2008, pp. 167–168).

Paavola and his colleagues provided a comparison analysis between the SECI and CHAT and they concluded that the models are more complementary than opposing. They have listed their main similarities and differences (Paavola et al. 2004).

- Both are knowledge creation models focused on innovation by conceptualizing learning as collaborative social process for developing shared objects of activity.
- Both emphasise learning as a dynamic processes, which has the power of transforming knowledge and practice.
- Both go beyond the "acquisition" and "participation" learning models, as described by Sfard (Sfard 1998).
- Both models have cyclical and iterative processes.
- Both models view knowledge creation as a fundamentally social process. Thus, innovation or intelligence arises from the systemic features of a whole community or organisation
- Both emphasize the role of the individual. Although, these models claim that innovation process is fundamentally social, individual activity viewed also as very important. In this respect, the activities of the individual are not seen as a separate and standalone, but as part of a stream of social activities.

- Both consider dialectical interaction between different forms of knowledge very important, and especially on how they can support the process of creating conceptual knowledge and conceptual models that can be used in subsequent activity. Therefore, both models emphases workshops.
- Both tell us how to develop shared objects of activities in an innovative way. In Nonaka innovation is more related to concrete products, while in Engestrom in new practices and activity systems.
- While Engeström criticised SECI for conflict free collaboration, Nonaka and Takeuchi acknowledge that in fact conflict will arise in dialogue, but trust and understanding, established via strong socialization, is what helps to overcome this conflicts and criticism and strive for knowledge innovations (Engeström et al. 1999) .
- The main difference is that SECI is a top down, while CHAT is a bottom-up innovation model. Also SECI is more focused on knowledge management in an organisation, while CHAT can be applied in any activity system or several connected activity systems.

Section 3.1.2 below describe and analyse how these two models of knowledge creation have been combined in 'Dynamic' roadmapping.

3.1.2 Limitations of SECI model for Knowledge Creation

'Dynamic Roadmapping' is viewed as a tool for collaborative strategic planning for systemic innovations and as such, it is very important, to develop a network infrastructure and a roadmapping process framework that will amplify the efforts, knowledge and experiences of the innovative communities in the field. *Roadmapping is regarded as a knowledge creating process for the involved stakeholders* (Li & Kameoka 2003), (Ma et al. 2006), (Kamtsiou et al. 2006). In accordance with the SECI model for knowledge creation, the roadmap activities are viewed as intertwined spirals that provide seed input for starting dialogues among the innovative communities, in order to externalise and amplify their knowledge within a wider European network (Kamtsiou et al. 2006). In addition, Conceptual ***modelling*** is combined with the *SECI theory of knowledge creation* in order to model, combine, share and negotiate the roadmapping knowledge among the innovative communities and their stakeholders.

SECI model for knowledge creation

According to Nonaka and Takeuchi new knowledge is created in an organization, when two types of knowledge, tacit and explicit knowledge are integrated and interact (Nonaka & Takeuchi 1995b). The key to knowledge creation is the four SECI modes of knowledge conversion: "*Socialization"* (sharing experiences and trust, therefore creating new tacit knowledge- from tacit to tacit), "*Externalization"* (articulating and converting tacit knowledge into explicit knowledge via dialogue- from tacit to explicit), "*Combination"* (systematic combining and re-structuring of explicit knowledge- from explicit to explicit), and "*Internalization*" (internalizing the new explicit knowledge by reflecting and embodying the explicit knowledge into tacit knowledge- from explicit to tacit). A knowledge spiral is created, when these 4 modes of interaction between tacit and explicit knowledge are *moving upwards* from the *individual*, to the *group* to the *organizational (company)* levels.

The SECI model is a Japanese approach to knowledge management, which serves as an alternative approach to the Cartesian dualism[3] of mind and body separation (and the subject from the object, the one who knows and the known, individuals and society,) usually rooted to the western philosophy. (Tuomi 1999) tells us that SECI model is closer to Vygotsky's learning theory "which address both, cognitive and social processes, which underlie the emergence of symbols, concepts, language and conceptual systems" (Ikka Tuomi 1999, p.328). (Engeström 2001) states that "In addition, Vygotsky's idea of cultural mediation of actions…. The insertion of cultural artefacts into human actions was revolutionary in that the basic unit of analysis now overcame the split between the Cartesian individual and the untouchable societal structure. The individual could no longer be understood without his or her cultural means; and the society could no longer be understood without the agency of individuals, who use and produce artefacts. This meant that objects ceased to be just raw material for the formation of logical operations in the subject as they were for Piaget. Objects became cultural entities and the object-orientedness of action became the key to understanding human psyche" (Engeström 2001, p. 134). Similarly, in SECI model, Nonaka and Takeuchi claim that this knowledge conversion is a social process between individuals and groups (Nonaka & Takeuchi 1995b), (Nonaka et al. 2000). The actual learning process is happening at several levels, e.g. *within an individual* (increased individual understanding, the individual learns through their interaction with another individual in intra-group level) and *intra-individuals* (increased shared collective understanding, e.g. two groups of individuals are interacting in an inter-group level) and takes place within a "community of interaction" (similar to a community of practice) *across intra* (e.g. same department within an organization) and *inter-organizational* levels (different departments within an organization) and boundaries (Nonaka et al. 2000). In this respect, SECI is similar to Lave & Wenger further interpretation of Vygotsky's concept of zone of proximal development[4] . Vygotsky's concept has gone through 3 interpretations: a) scaffolding, b) cultural and c) collectivistic perspective, where (a) and (b) focused on learning within an individual in his social context, will c) focused on collective learning happening intra-individuals (Tuomi 1999). In addition, although the predominant form of knowledge in the west is considered to be explicit knowledge, a form of formal knowledge easily transmitted across individuals mainly as information, the Japanese rather view knowledge as *primarily tacit*, not easily to identify and express, but which is rooted in an individual's intuitions and actions and experiences (Nonaka et al. 2000) (Nonaka & Konno 1998).

According to Nonaka, there two types of knowledge take place in knowledge conversion, tacit and explicit. *Tacit knowledge* includes both cognitive (such as schemata, paradigms, perspectives, believes, motives, perceptions, hypothesis, mental models, assumptions, etc.) and technical aspects (such as skills, crafts and knowhow). *Explicit knowledge* includes types

[3] Cartesian dualism http://psychologydictionary.org/cartesian-dualism/

[4] "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (Vygotsky, 1978:84-91)

of organizational assets which are formalised and are easy to be transferred and combined, such as databases, brochures, manuals, procedures, etc. The SECI model tells us how knowledge is emerging in an organisation and how it is transformed into various knowledge assets, such as organisational concepts, models, and structures. Nonaka and Konno also talked about an ontological concept they call *"ba"* (Nonaka et al. 2000) (Nonaka & Konno 1998), a Japanese context which means space. In this space, the physical and the conceptual co-exist and boundaries between individual and collective minds are merged. Ba fuses the physical (for example company's offices, stores, etc.) with the virtual (for example google documents, skype, websites, etc.) and mental (for example shared motives, visions and experiences, etc.) spaces. The ba concept resembles the western concept of *'community of practice'* (Wenger & Snyder 2000), as a place of interactions among individuals, who share a common language and culture. It is important that the middle managers are creating and maintaining several ba for enabling successful knowledge conversion, as they are the shared contexts in which new knowledge is created. There are four (4) types of ba, which corresponds to the 4 modes of knowledge conversion: *"originating ba"* supports "socialization", *"dialoguing ba"* supports "externalisation", *"systemizing ba"* supports "combination" and *"exercising ba"* supports "internalization" (Nonaka et al. 2000).

A proper knowledge environment, design processes and procedures which can help facilitating innovativeness and creativity are indispensable for creating and sharing knowledge (McCarthy 2003), (Brown & Hare 2001), (Groenveld 2007), (Nonaka et al. 2000). PROLEARN[5] Network of Excellence has first utilised the SECI model to develop its own roadmapping framework (Kamtsiou et al. 2006). The PROLEARN roadmapping process framework (Figure 49) was derived from the general SECI process framework (Figure 48) by replacing the triplet of social entities {Individual, Group, and Organization} with {Core Partners, Associate Partners, and Scientific Community & Industry}.

The roadmap was considered to *be a learning process of knowledge transformation cycles* - from *tacit* (stakeholders' implicit visions and knowledge) to *codified* (expressed visions – scenarios, actions) forms. Each of the key Roadmapping activities of Futures, Gap Analysis, and Roadmap Recommendations for Action were being continuously expanded and updated through the SECI process, via the interactions of the Network of Excellence with many stakeholder communities. The input from these discussions was analysed and modelled using conceptual modelling tools, in order to be able to identify the essential concepts and processes and their complex relationships in various contexts, and to visualize them in a way that can be communicated to – and elaborated by – various stakeholder groups. Knowledge therefore is ***spiralling*** across the core partners of the PROLEARN network of excellence to its associated partners to external stakeholders from science and industry (Kamtsiou et al. 2005), (Kamtsiou et al. 2008), (Kamtsiou et al. 2006), (Naeve et al. 2005).

[5] Prolearn: a European Commission IST FP6 Network of Excellence, which also developed a roadmap for Professional Learning using TEL.

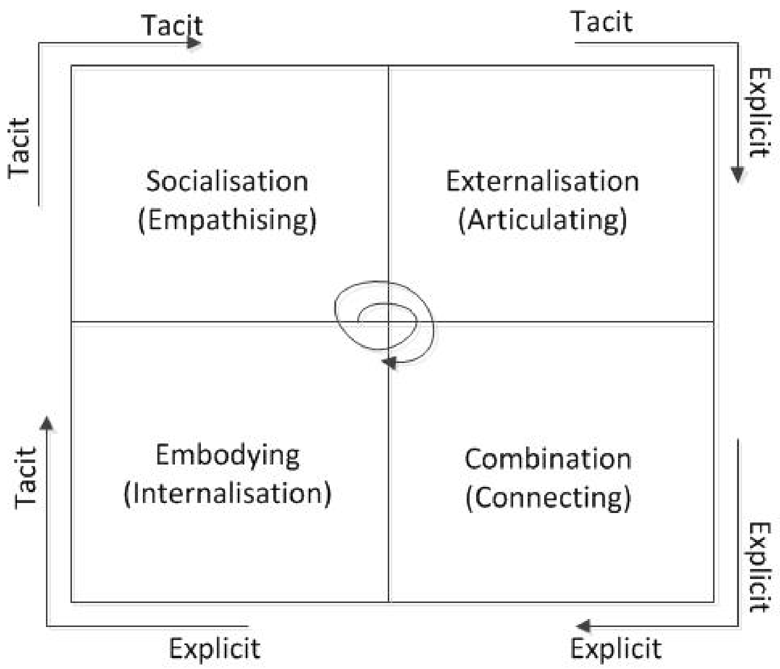


Figure 48. The SECI spiral of knowledge creation. increasing understanding through experiencing, articulating, deducing and reflecting. Adapted from (Nonaka et al. 2000) *from figure 3, p.10*

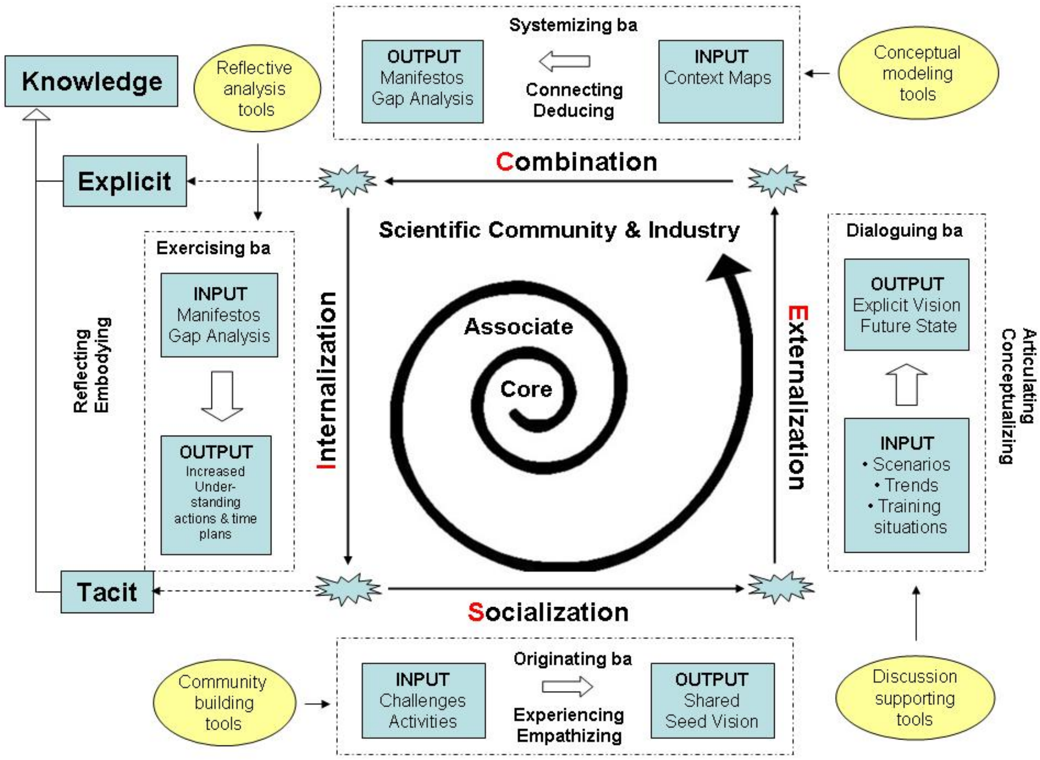


Figure 49. PROLEARN Roadmapping framework based on SECI, author's own compilation from (Kamtsiou et al. 2006) *from figure 3, p.167*

Limitations of the SECI model

This enhancement of the mainstream roadmapping framework is an especially important improvement for roadmapping, since the roadmap is a commonly agreed and accepted vision, and not a mechanically derived result (Kamtsiou et al. 2006). PROLEARN extended the roadmapping activity to go beyond strategic planning e.g. time2learn[6] roadmap, to be dealt as a knowledge creation process for its community. In addition, it added conceptual modelling as a core of the roadmapping activities, in order to facilitate the stages of convergence and synthesis of the new knowledge, thus transcending individual understandings to increased collective shared understandings. The resources available during PROLEARN project did not allow for investing effort in developing methodologies to identify threats that could challenge these visions and would risk the implementation of the desired future. At the same time, although the SECI model did provide an understanding of how we go from representation of knowledge to dynamic knowledge creation, and what is involved in this transmission, it did not provide any means for managing the knowledge creation. SECI model of knowledge creation only tells us what the types of knowledge conversion that can apply in knowledge creation are and how they appear. In that sense, a complementary mechanism is needed in order to better determine the relevance of the strategic issues identified, the seed input chosen as a starting point for discourse, and the management of knowledge creation in terms of increasing the motivation of communities to participate, as well as manage effectively any conflicting interests, tensions and power structures in these communities.

Since, the SECI model has some limitations when applied as a knowledge creating framework (Engeström 1999), (Engeström 2001), (Tuomi 1999), (Gourlay 2006), (Engeström 2008), consequently, several questions arise when SECI is applied as a methodological theoretical framework for roadmapping. These questions and the related challenges are described below:

Are there clear boundaries between the SECI modes of knowledge creation?

Although it was assumed by Nonaka and Takeuchi that there are clear boundaries in knowledge conversion, for example there is no explicit knowledge involved in socialization, or tacit knowledge in combination, in reality this separation is quite artificial. Let’s consider *‘combination mode’*, in case of roadmapping, for example, there is tacit knowledge involved when systemizing, making sense, modelling and combine individual explicit visions and existing knowledge. In addition, some internalisation of knowledge is produced when reflecting, combining and abstracting explicit information. In *‘socialization mode’*, it is difficult to imagine any shared experiences and activities without any dialoguing or sharing of explicit prior knowledge. In ‘internalisation mode’, which is closer to learning by doing activities, we can assume that some combination and systematization of knowledge is still going on while the roadmapping actions are realised. In *‘externalisation mode’*, socialisation and trust are important aspects of effective dialogue. Moreover, in terms of mental models (as

[6] Time2Learn: a thematic network under the European Commission IST, FP5. It developed an R & D roadmap for European professional eTraining.

it was demonstrated in PROLEARN (Kamtsiou et al. 2006)) during '*socialisation*', individuals might also combine tacit knowledge through the sharing of common experiences and observation. While during '*externalisation*', some knowledge is also internalised in the form of new tacit background structures that will support the explicit knowledge. Therefore, the linearity that is implied in knowledge conversion starting from socialisation, to externalisation, to combination and to internalisation modes does not exist. Polanyi for example argues *that tacit knowledge is a precondition for explicit knowledge* and the one *cannot be separated* by the other. In that sense, *tacit knowledge is the background for the sense making* of the explicit knowledge (Tuomi 1999), (Gourlay 2006), (Tsoukas 2005), (Polanyi 1997) .

What drives SECI spirals for creating new knowledge?

The initial problem that kick starts the SECI cycle is not explicit (Engestrom 1999b, 2001), (Tuomi 1999), (Engeström et al. 1999), (Engeström 2008), (Engeström 2001). Bereiter (2002, pp. 174-185) cited by (Paavola et al. 2004) also recognise this problem: "while the theory recognises knowledge abstracted from context, it says little about how it can be managed". Therefore, the following questions are arising: What drives the SECI model of knowledge creation adopted by the PROLEARN project? How we can ensure that the right stakeholders, experts, communities are involved in the process and how we can increase the internal motivation of such communities to collaborate? How to make sure that we continuously support and feed this knowledge creating process with the involvement of new communities, new ideas, and visions? How to determine whether the challenges have been well identified, prioritised correctly, and whether the actions planned have been well chosen? Are any important technologies missed? Are any recent developments or any other factors that can provoke changing that need to be taken into account? Are there other communities who have conflicting interests and visions? Are the roadmap visions/scenarios desirable? Are there any political, economic, social power structures that will hinder the Roadmapping progress (PESTLE – drivers: Political, Economic, Social, Technical, Legal, Environmental drivers)?

How the knowledge created can be spiralled and communicated within the boundaries of individual, organisation and outside communities?

The SECI model is applied within an organization or a specific community of practice, therefore it is difficult to be transferred and communicated to outside communities and other stakeholders. In our case of 'meso level' roadmapping, the individual visions of certain stakeholders need to be negotiated and agreed with all necessary actors, who are important for their implementation. In addition, the internal knowledge from different communities, such as researchers, practice, industry, needs to be exchanged and synthesised. Therefore, a more comprehensive ***adoption model*** is need for the roadmap implementation and its effective communication.

The rest of this section describes how 'Dynamic Roadmapping' model addresses these challenges. Sections 3.1.3, 3.1.4 synthesise SECI and CHAT a systems to thinking perspective. Finally, section 3.1.5 shows how these challenges were 'addressed at practical methodological levels by integrating Roadmapping, Foresight and Change management methods.

Challenge A: No clear boundaries between the SECI modes of knowledge creation.

Similarly to the PROLEARN methodology, the process framework for 'Dynamic Roadmapping' is considered to be *a learning process of knowledge transformation cycles* - from *tacit* (stakeholders' implicit visions, assumptions, and knowledge) to *codified* (expressed visions – scenarios, action plans) forms. The 'Dynamic Roadmapping' process framework depicted in Figure 50 was derived from the general SECI process framework (see Figure 49) by replacing the ontological dimensions {Individual, Group, and Organization} with {Individual stakeholders, 'co-innovation' group, and extended environment, e.g. TEL Scientific Community & Industry}. The key in this categorization is to create a *'community of practice'* in order to act as a *'co-innovation'* group of stakeholders, who between them have the resources, knowhow and the authority to develop, implement and continuously update and coordinate the dynamic roadmaps. This value network of stakeholders represents a *'meso' level roadmapping* in between (micro) company roadmaps and (macro) science and industry roadmaps.

Furthermore, in order to better capture the key interactions between tacit and explicit knowledge involved in each mode, the SECI model is re-defined as four main types of parallel activities: a) socialization – externalization activities, b) externalization – combination activities, c) combination – internalization activities, d) internalization-socialization activities. Correspondingly the types of knowledge convergence are: in a) from tacit to tacit to explicit, b) tacit to explicit to explicit, c) explicit to explicit to tacit, d) explicit to tacit to tacit (see Figure 50). As noted above, it is recognised that 'Combination and Socialization' as well as 'Externalisation and Internalisation' are also going on in parallel since there is some dialogue that goes on when explicit knowledge is combined and some reflection and at least mental testing is going on when we externalise and formalise tacit knowledge. Therefore, similarly to Polyani's view of tacit knowledge (Tuomi 1999), (Polanyi 1997), Socialisation and Internalisation activities act as the background knowledge (support knowledge) which provides the sense making of the Externalisation, Combination formalized knowledge activities. Socialisation provides the social platform for developing trust, and sharing experiences. Internalisation provides the means for reflecting, testing and acting on externalised and combined knowledge trough learning by doing and reflection activities. Externalisation and Combination are mostly going on in parallel, since usually when knowledge is formalised some combination with prior knowledge is taking place.

According to the above analysis, the focus is more on the 4 activities in the S-E, E-C, C-I, I-S because they provide a good classification of the main roadmapping processes involved in 'Dynamic Roadmapping', which related to Dynamic knowledge creation. Nevertheless, it is acknowledged that Externalisation – Internalisation is also going on in parallel as the new externalised knowledge is supported by some tacit background knowledge.

As illustrated in Figure 50, during the ***(a) Socialization-Externalization activities,*** individual stakeholders provide specific seed input to be used for initiating a general discourse via brainstorming and informal meetings in the form of learning cafes, workshops, and by using a specialised website[7] and social media platforms (e.g. in TEL case study this involves: TEL related research projects, standard bodies and experts, tools and learning solutions developers, content providers, educators, schools administrations, teachers and parents associations, industry representatives, politicians, etc.). The main goal of these activities is to *capture, record and express* the perspectives of different communities, without making any judgements, in order bring up and express as many early (implicit) ideas as possible, and gain a clear overview of the diverse interests and activities, motives, assumptions of the different stakeholder groups and possible tensions in the domain. In this way, we moved from *individual understandings* to more *shared individual understandings* of topics, approaches and influencing factors applied in different contexts. During this phase, social platforms such as google documents, web spaces, learning cafes, conference workshops, surveys and conceptual modelling tools and methods such as Social Networking Analysis (SNA), bibliometric, text and topic mining, surveys, interviews) are used in order to capture and record the information, which will be used as raw input for building the cartography of the domain, but also to develop, the social roadmapping platform for both the 'co-innovation' group and for its transactional environment (other stakeholders that the 'co-innovation' group interacts and deals with).

During the ***(b) Externalization-Combination activities,*** the results from these initial dialogues in (a) are articulated, conceptualised and catalogued in an initial cartography map of the schools domain in the form of conceptual maps, and collections. This cartography provides a bottom-up approach to form *the initial 'co-innovation' group* of innovative communities (i.e. establishment of a 'co-innovation' roadmapping group in the area that produces specific positions), who will be responsible for the development and implementation of the roadmap. The cartography is then fed back to the 'co-innovation' group, during a course of managed discourse, through negotiation meetings (face to face and online), in order to be able to focus on specific activities and outcomes. These, then will be negotiated by the community at large, as alternative futures and decisions, which underlie and affect the 'co-innovation's group desired future. In this way, a negotiation management approach was achieved where alternative actions for development are debated, judged and integrated into the roadmap**.** This lead to a *shared desired future* and a *shared collective understanding* of the issues involved. During these stage, the use of Search Conference (Emery & Purser 1996) and the 'future search methodology (Weisbord & Janoff 2000) are used as tools for negotiating and selecting the initial visions and desired scenarios, recording trends and other factors that might affect these visions. A historical analysis of shared experiences and innovation milestones is also done, by the 'co-innovation' group, as an initial step of Future search methodology, followed by scenario planning (desired scenarios and trends analysis). Learning cafes[8] and online skype meetings are used during this stage together with a shared google document in order to facilitate the future search and roadmapping events and their follow up online meetings. An observatory is also developed,

[7] http://www.learningfrontiers.eu
[8] http://www.theworldcafe.com/method.html

which includes the cartography, the desired futures and the trends and signals that might affect these futures.

During ***(c) Combination – Internalization activities***, the results of this managed discourse from (b) are systematised and reflected using conceptual modelling tools to clearly systematize concepts, identify patterns, factors influencing these concepts and analyse their relationships. The explicit knowledge of the desired futures which was negotiated in (b) is reflected and synthesized into a *knowledge system* in the form of initial roadmaps, during face-to-face workshops and follow up online discussions. These roadmaps and their desired futures are then *contextualised*, and then *stress-tested* in the various regional, economic, political and market contexts identified in the domain cartography. These different contexts chart the key aspects of the domain in the form of distributed context maps and plausible *future contexts scenarios*. The use of context scenarios informs both the desired future scenarios and the roadmaps and provides a range of possible contexts, against which the roadmaps are implemented. Thus, they represent the new background context structures against which, the explicit knowledge is making sense, as well as a way to test the externalised (explicit) Knowledge. They also enable the identification, monitoring of weak signals, tensions and other factors that might influence the desired scenarios of the roadmaps and the roadmapping actions. The roadmapping artefacts are stress-tested against these contexts, using both the combined knowledge of the explicit expressed scenarios, and the tacit assumptions, preconditions and prior knowledge of the group. Search Conference and follow up face to face and virtual workshops are used in order to first develop the context scenarios and then stress-test the roadmaps against them. This leads to *an increased shared collective understanding* of issues involved and their contexts. Tools during this stage are conceptual modelling tools to facilitate modelling of the knowledge systems, learning cafes to facilitate development of context scenarios and stress testing of the roadmaps. During this stage the observatory is also updated with the context scenarios.

During ***(d) Internalization- Socialization activities***, the resulted explicit knowledge and plans from (b) and (c) are embodied, experienced and internalised through actions and hands on implementation of the produced roadmaps. This learning by doing that takes place in (d) enables the updating of both visions and operational plans, as new opportunities are developing and new ways of implementation are becoming possible. The observatory function is also expanded in order to monitor and update the roadmapping actions. Such function is very important in order to publish, disseminate and continuously test if the justified explicit knowledge (articulated as concepts and concrete plans) developed by the co-innovation group is viewed as important and applicable by external stakeholders in both the co-innovation's transactional environment and in the community at large. *Thus, going from 'diverse beliefs' in (a) to 'selected justified beliefs' of the co-innovation group in (b) to 'tested justified beliefs' in (c), to 'true adopted justified beliefs' in (d).* Tools during this stage are new research and development projects; modelling and data analytics tools such as bibliometric and social analysis tools, which are used in order to update the roadmaps, the cartography, the desired and context scenarios and update the observatory. This leads back to a *new individual understanding* of the issues involved. The issues, which come up from the active roadmaps implementation are communicated and disseminated via the co-innovation group and the observatory to external communities from academia/research, policy and industry thus, starting a new cycle in updating the roadmaps. The aim of the activities is to facilitate the discussions with the different groups working in this domain and shed light into: the landscapes of plausible desired futures; what keeps us today from achieving these futures; as well as provide an indication of where the possibilities are compared to today's realities. In this approach, similar to foresight (Barré 2001), *the Roadmapping exercise* consists fundamentally of a succession of extension and concentration steps. The Roadmapping participants (the 'co-innovation' group) interact with themselves and other external stakeholders in an exploration and hypothesis-building stage (*extension*: general discourse – expansion of ideas), followed by a selection-, convergence-, and synthesis stage (*concentration*: negotiation/deduction – managed discourse) (Kamtsiou & Klobučar 2013). This bottom-up strategy from general discourse to managed discourse via scheduled interactions with various stakeholder groups is illustrated in Figure 51.

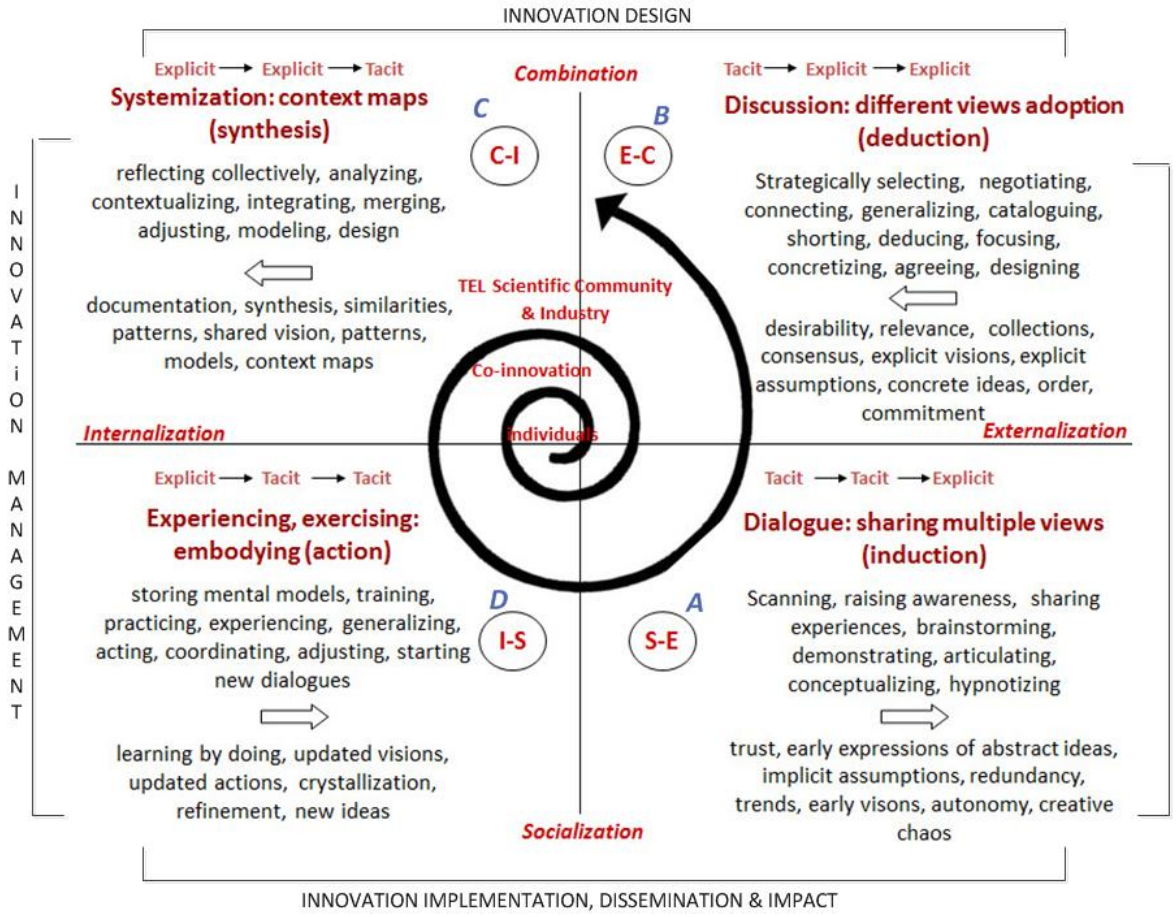


Figure 50: 'Dynamic Roadmapping' activities spirals in accordance to SECI

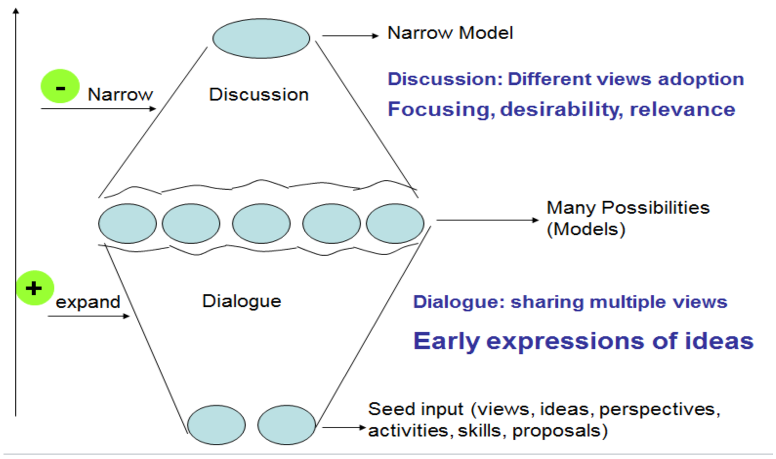


Figure 51: discourse process: From dialogue (general discourse) to discussions (managed discourse)

Examples of the 'Dynamic Roadmapping' activities involved in each of the 4 modes are given in the Figure 52 below:

C-I ***(C)* Building the roadmaps, and combine resources** • Perform Foresight analysis and development of contexts scenarios (contextual design) • Development of initial roadmaps (actionable design) • Stress-test desired futures and initial roadmaps under Context Scenarios • Update cartography to include shared desired futures, context scenarios, roadmaps • Tools: Future search/Learning Cafes/workshops, modelling tools, GoogleDoc, updated observatory, web portal, templates	**E-C** ***(B)* Disagreement management and linking knowledge** • Creation of initial domain Cartography • Initial Co-Innovation group creation based on common activities and shared interests (input from Cartography) • Development of Co-Innovation group's Initial visions (ideal design) • Co-innovation group agrees on Shared desired futures • Tools: Future search events , online follow up meetings, modelling tools, collaborative writing tools (e.g. GoogleDoc, content management and CRM tools), updated observatory, web portal, templates
I-S ***(D)* Learning by doing, reflecting, monitoring** • Operationalise plans • Development of projects (R&D) • Implementing roadmapping actions • Monitoring Roadmaps via observatory • Update cartography, desired and context scenarios and roadmaps • Start new dialogues • Tools: research projects, development projects, modelling tools, adoption models, observatory, web portal	**S-E** ***(A)* Connecting & Dialoguing** • Collecting and recording Initial cartography input • Collection of motives, perceptions, assumptions, tensions • Shared history and innovation milestones • Identification of Research areas & projects, industry players • Collection of Trends, scenarios, weak signals • Tools: Learning Cafes/workshops, surveys, desk-top research, Delphi, observatory, text mining tools, social networking analysis tools, SNA tools

Figure 52. Examples of 'Dynamic Roadmapping' framework according to modified SECI explained in Figure 64.

Challenge B: What drives SECI model and how we can deal with tensions and disagreements?

Nonaka, Toyama and Konno (Nonaka et al. 2000) assume that in order for new knowledge to be created dynamically, a *vision must pre-exist in an organization*, which will drive and synchronise the SECI process. The creation, articulation and communication of this vision, inside and outside the company are the role of top management. This is a *top down approach*, which applies to a single organisation. Moreover, the authors argue that this vision will define, and determine the organization's value system, and the quality of knowledge that will be produced. It also assumes that everyone in the organization is complying and agrees with this vision.

In case of *'meso-level' roadmapping*, many stakeholders coming from different organisations and/or networks of organizations need to agree and develop a shared vision to act as a common visionary framework. Bringing together the right stakeholders, who will form this 'meso-level 'co-innovation' network is of critical importance and will determine the kind of knowledge and visions they will produce. A top-down approach of developing the 'co-innovation' network will not work in case of meso-level roadmapping, *since there is no single top-down vision or problem that these diverse stakeholders already automatically abide* to, or *a single culture* or *language* that they all share. Consider for example the TEL school domain that has been used for developing this roadmapping case study. Innovations in schools require the mobilization of several stakeholders such as teachers, students, parents, industry community leaders, researchers, tools and software developers, schools administrations, politicians, etc. These stakeholders' communities are characterised by different cultures and languages. Moreover, a shared vision, which needs to be created by these stakeholders, should be in agreement with the stakeholders' own motives, goals, and desires, as well as those of their organizations and/or the networks they represent and it should then be materialised, via collective activities on planned actions. It is often that these schools stakeholders would have conflicting visions and motives. SECI on the other hand is often criticised as a conflict free zone, where smooth collaboration is always possible and no one loses. Engeström criticise this as a key problem with Nonaka and Takeuchi's model. He also states that SECI makes the assumption that "that the assignment for knowledge creation is unproblematically given from above. In other words, what is to be created and learned is depicted as a management decision that is outside the bounds of the local process. This assumption leads to a model in which the first step consists of smooth, conflict-free socializing, the creation of 'sympathized knowledge' as Nonaka and Takeuchi (1995) call it" (Engeström 2001, p.151).

Strengthening the intelligence[9] aspects of roadmapping, and involvement of the right stakeholders: Cultural Historical Activity Theory –CHAT and Weak Signal Analysis

To make sure that the conflicting interests and weak signals are observed and analysed, the roadmapping process is supported by applying aspects of the Cultural-Historical Activity Theory - CHAT and from Weak Signal Analysis. CHAT theory provides the conceptual tools to understand capture and synthesise the multiple perspectives, and the different networks of stakeholders (innovative communities) and their interacting activity systems in the domain, sector or segment. In that respect, CHAT theory is used in order to: a) form the

[9] Intelligence: capturing and using the right information, involving the right people, in order to make effective decisions and take effective actions. It could relate to technical, competitive, economic, research intelligences

co-innovation group, i.e. bringing together shareholders based on their shared interests, (objects) and activities; b) making sure that the roadmapping methodology takes into account the stakeholders' requirements that might have been ignored by the initial co-innovation group; and c) make sure that not only the dominant views of the most influential stakeholder are taken into account. This serves as a *bottom up mechanism*, in order to better understand and choose the strategic issues (units of analysis in the roadmap), the seed input chosen to be used as a starting point for discourse, and manage the knowledge creation in terms of increasing the motivation of communities to participate, as well as to manage effectively any conflicting interests of these communities. The aim is to *support and strengthen networks of people that are connected by shared objects (what they investigate, produce) through common activities, tools and shared spaces* (Kamtsiou & Hoel 2009), (Kamtsiou & Klobučar 2013), (Kamtsiou & Olivier 2012).

Cultural-Historical Activity Theory (CHAT)

There are three generations of Cultural-Historical Activity-CHAT research by Lev Vygotsky 1978, extended by Alexei Leont'ev in 1978 and 1981, and Engeström in 1995. Engeström has developed a theory of expansive learning (Engeström 2001), which has several similarities and some differences to the SECI model. Activity theory uses extensively, the concept of externalisation and internalisation of knowledge, but in this case the knowledge cycle, unlike SECI it always starts with questioning (i.e. a specific problem that emerges from some kind of tension and requires solution). The model is based on 6 stages (see Figure 53) (Engeström 2001).

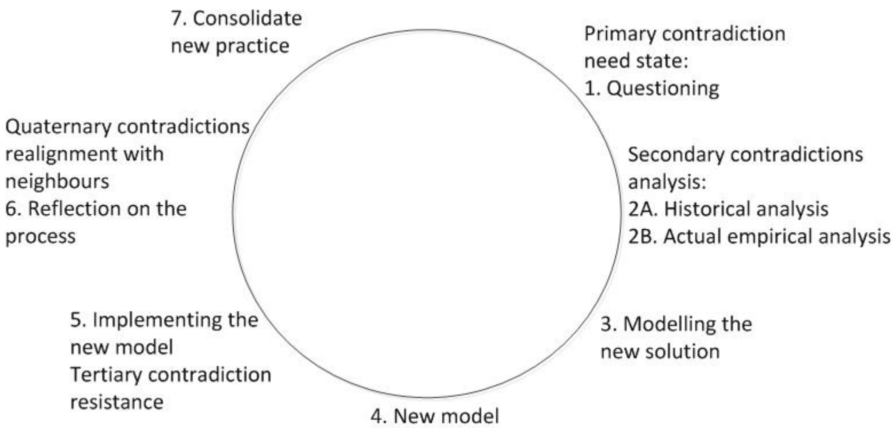


Figure 53. Expensive learning cycle and contradictions. Figure adapted from (Engeström 2001) from figure 11.p.152

(Engeström & Sannino 2010) argues that "in expansive learning, learners learn something that is not yet there. In other words, the learners construct a new object and concept for their collective activity, and implementing this new object and concept in practice". Similarly, we can argue that in 'Dynamic Roadmapping', the 'co-innovation' group construct a new object 'their visions and desired scenarios for the future' and 'their roadmaps', and implement them collectively in practice. In addition, this object is not fixed, but changes as new information becomes available or as new opportunities become apparent through the realization of the actions. Activity theory, like the

SECI model, is also a dialectical theory, but unlike SECI the emphasis is on contradictions rather than smooth collaboration.

In his CHAT model (Engestrom 2009) describes activities as dynamic relationships among:

- Agents: individual subjects (people)
- Communities: To which subjects belong and with which interact
- Objectives: The conceptions the agents have of the purpose of their activities.

These relationships generate outcomes which are facilitated by:

- Tools: instruments used by Agents when carrying out the activities
- Concepts: used and defined by Agents
- Roles: the role system and division of labour adopted by the communities of Agents.

Activity theory *separates learning process* and *implementation*. The objects provide the purpose of the activity related to the actions 'what'? What are we trying to do? Operations are related to – 'how' will we achieve it, which tools, processes, instruments? Technology is at the level of operations. Similarly, Roadmapping separates the strategic process of 'what we are trying to develop and why', from the operational process of 'how' we are going to develop them.

Engeström uses the term *runaway objects (the intended purpose behind the agents activities),* as objects that are disputed and produce opposition and controversy. These objects could escalate to major conflicts at a global scale of influence (Engeström 2008). Unlike SECI model, which emphasize smooth collaboration, according to Engeström, very important are the contradictions that are found among the objects of different activity systems as well as among other parts of different activity systems. These contradictions can escalate and becoming serious conflict zones (Engestrom 2011). Figure (54) illustrates how Engestrom represents the activity system as an "object oriented system" (Engeström 2001), (Y. Engestrom 1987)

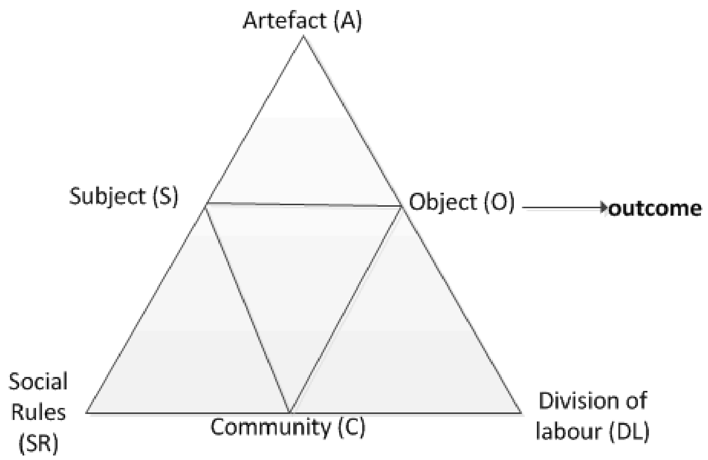


Figure 54: Second generation Activity System based on Vygotsky's basic mediated action triangle, adapted from (Engeström 2001) Figure 3, p. 135.

In third generation Activity Theory (Engeström 2001), (Engestrom 2009) several activity systems are connected via their partially shared objects, with at least two activity systems as a minimal unit of analysis, as shown in Figure 55 These objects are concerns "they are generators and foci of attention, motivation, effort and leaning. Through their activities people constantly change and create new objects. The new objects are often not intentional products of a single activity but unintended consequences of multiple activities" (Engeström 2009) .   Moreover, "the object gives durable direction and purpose to activity: it is the true motive of activity (not reducible to conscious goals); the object is a moving target, never fully accomplished: a horizon of possible actions; and the object is multi-faceted, a mosaic of multiple interpretations, voices and positions. The object resists and kicks back" (Engeström 2009). In a way, this theoretical framework is used to map the 'invisible battlegrounds' which are only understood when looking for disruptions, tensions, and conflicts, which have the potential to interrupt the interacting activity systems. Similarly in our roadmapping methodology these 'voices and positions' of the different actors and communities are captured, recorded, categorised, and modelled in order to identify the tensions areas and build the cartography of controversies in the domain.

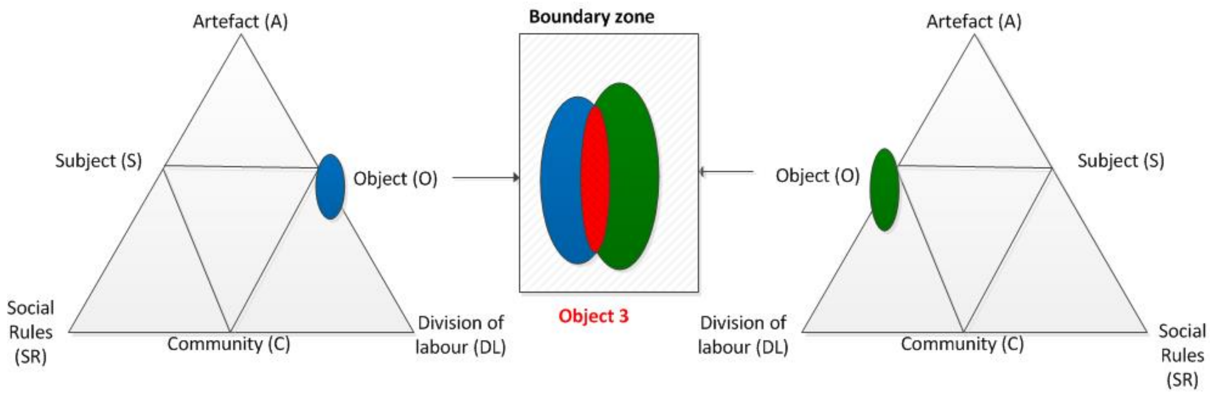


Figure 55:   Third generation CHAT: Based on Engestrom (2001) figure 3, p.136

In the 'Dynamic Roadmapping', the relationships between *people and issues* are identified, and modelled in the *domain cartography*, with a special focus on the shared objects of the particular networks and the rules and practices that the different activity systems are built up. For example the TEL schools sector involves many communities and groups of stakeholders who have different motives and interests. For example an e-learning technology roadmap of an educational institution is different from a content provider's technology roadmap, or a tool developer's roadmap. How can the groups or individuals, who are the roadmap stakeholders a) influence what is included in the roadmap, b) can they observe, follow and later evaluate what was on the roadmap? A simple example: A content provider (CP) develops their technology roadmap and takes action accordingly - then maybe an educational institution later observes that the CP is providing standard interfaces to their contents, and the CP themselves can evaluate whether the implementation of standard interfaces was beneficial. The questions that rise are: How to establish a framework we need to aim at activities that are long term in order to provide a home for the achievements of the different stakeholders, but also provide a platform/stage to the future projects? How to integrate support from different directions into Roadmapping activities and foster collaboration and synergies across specialised communities, who are developing different types of roadmaps for the area? By identifying the different activity systems involved, we can understand the objectives, desired outcomes and tensions of the innovative communities. Thus, the innovative communities, who are brought together to form the co-innovation group and develop the roadmaps are internally motivated by their efforts to transform their objects *(the purpose for their activities)* into desired outcomes and eventually transform themselves, via this *expansive learning*. This motivation justify the collective actions that are performed by the actors participating in the innovative communities (Blin & Jalkanen 2014). The 3rd generation of CHAT provides an understanding of how the different activity systems interact based on their diverse perspectives and motives. If we look at the roadmap as being comprised of different activity systems, driven by specific objectives, then we can understand the *'secondary contradictions'* (macro tensions and problems mapped in the domain cartography), the *'tertiary contradictions'* (internal contradictions related to resistance within the co-innovation group to implement the roadmapping outcomes) as well as the *'Quaternary contradictions'* related to contradictions and synergies with their neighbouring activity systems (other external stakeholders that need to be aligned in implemented the roadmapping outcomes).

Figure 56 shows an example of how four different types of actors, i.e. standards experts (& researchers), tool developers, curricula developers and teachers are connected via the 'co-innovation' Roadmapping group through their shared objects and their common or complementary activity systems and networks. The overall shared object among these communities could be broadly defined as: "Find new ways of learning practices supported by technologies and integrate them into schools, in order to transform schools from closed institutions to open learning creating environments". Some of the '*objects'* of 'Dynamic Roadmapping' for TEL are for example the development of *specifications* (related for example to different assessment methods, competency models, curricula development, and development of shared learning repositories), *learning tools* and *software*, *learning and teaching practices*, which are supporting schools as 'creative learning environments'. For example, standardised competency and assessment methods will contribute to the development of more effective personalised curricula and provide evidences of knowledge and skills, both prior and after the learning experience. These 'objects' are shared by several *activity systems*. The acronyms used in the figure indicate standard Activity Theory elements: community (C), Tools and artefact (T&A), subject (S), object (O), social rules (R), and division of labour (DL).

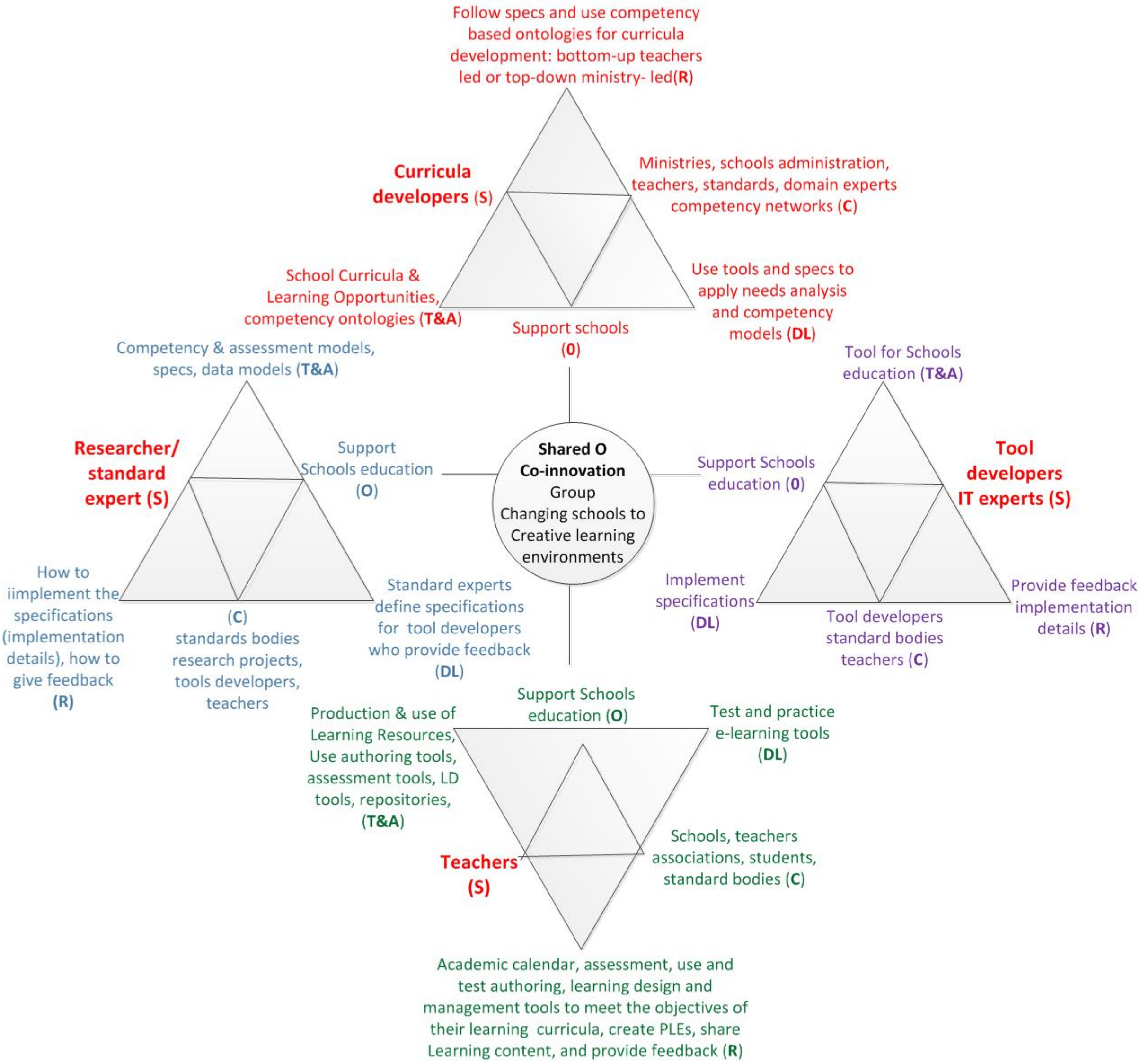


Figure 56: Examples of activity systems in outcome-based education

For example, standards experts & researchers identify concepts, specifications, data models, etc.; curricula developers use competency models and specifications to develop curricula and identify learning opportunities and provide feedback to standard bodies and teachers; tool developers develop tools based on specifications, test specifications and provide feedback to standard bodies; teachers use and test tools in order to develop, share and re-use learning content and provide feedback to tool developers. They also use and combine the tools in order to build personalized learning environments for students. Then, they give feedback to both tool developers and researchers. In doing so, teachers develop new learning practices, interpret the guided curricula, identify the intended learning outcomes and provide feedback to curricula developers (Kamtsiou 2013).

Disagreement Management through Conceptual modeling, and cartography: capturing and bring in the voices of TEL communities

CHAT perspective provides the means to identify the different activity systems and their respective objects in order to map out the motives, actions and assumptions of the involved innovative communities, their organisations, individuals and their networks and determine what drives these activities. These will allow us to capture, record and classify the ‘voices’ of different communities in TEL and to look for possible tensions, contradictions and power structures that could affect the plans and visions of these communities (their objects) as well as possibly drive some of the dialogues in the SECI process. Towards these goals, conceptual modelling tools, surveys, interviews and social platforms, and a web-based portal are used *to support disagreement management and the development of the cartography.* The main idea is to build connections based on shared concepts that link a multitude of different perspectives, by offering an overview, and by inviting active participation (e.g., commenting, linking and refining each other’s concepts and/or inter-concept relations). Consequently, SECI Roadmapping methodology is extended, so *that it supports and emphasises management of disagreements* and better fit the observed patterns of interaction between the different stakeholders and their goals (implicit and explicit). The aim is to *map these interactions* in domain model, which allows the roadmap’s stakeholders to get a better view of what is going on inside the communities, as well as how the communities interact with other external communities/stakeholders (Kamtsiou 2013).

The aim is to bring input and people/networks from research, practice, industry and policy makers in order to identify the following:

- *(Why?) – Outcome:* what are the expected and desired outcomes of the different activity systems?
- *(What?) – Objects:* What are the objects of their activities that they intent to transform into the desired outcomes?
- *(Who?)- Subjects:* Who are the actors of the activities, their histories, and what they bring into the system (e.g. motives, skills, knowledge, practices)
- *(How?) – Tools, Rules and Division of Labour:* What are the tools, technologies, operations they are using in order to transform their objects?
- *(Where?)- Tensions/contradictions:* are there any tensions within and inter activity systems? How the results are contextualised?

Conversations are used with these stakeholders as support for getting different intelligence (market, competitive, technical), in order to a) inform the roadmapping process around topics of interest, visions, goals, motives, innovative ideas and also to b) empower those likeminded to use these roadmaps to find and connect with potential collaborators. Normative type of questions (**what it should be…)** as well as exploratory questions (**e.g. what if…. Or what can be…**) are used in order to identify the community’s visions, and explore plausible contexts scenarios (what if…) and the potential of the new technologies (what can be...). As (Y. Engestrom 1987) states a central principle of CHAT is that human beings do not live alone in a void, but are embedded in their sociocultural contexts and that their behaviour cannot be interpreted independently of these contexts. Moreover, in order for the roadmap innovations to be sustainable, they must be interpreted into contexts. These different contexts are described in the form of **Context scenarios**, in which the desired futures and objects of these communities are played out. The activities related to cartography, and the development of context scenarios are described in detail in the case study chapter 6.

Applying weak signal analysis to continuously connect Roadmapping to emerging reality

Since roadmapping is a forward looking activity, it is easy not to pay enough attention to the historical context of the identified issues and trends. Therefore, the CHAT concept of 'contradictions' has been used, in order to make sure that we are able to identify the trends and *"weak signals"* that might potentially change the contexts that the roadmap are operating and consequently, the effectiveness of the roadmap (are we aiming for the right goals), and its efficiency (operational part). To this end, an integrated model for the creation of such an "insight tapping" system is developed, which grounds these modelling and foresight activities on theoretical understandings of how you learn to cope with uncertainty in a disruptive environment. Weak signal analysis and development of context scenarios are employed. In order to capture the weak signals, text mining, blogs analysis, bibliometric, and Delphi techniques were used. This is further analysed in chapter 6.3.2, 6.3.3, 6.4.3, 7.2.2.

Observatory Function Needed to Adapt Roadmaps in a Turbulent Environment

As already mentioned above, Engestrom tell us that the objects of the activity systems are moving targets, which are never fully accomplished. Similarly, the roadmap should be a continuous process that keeps the feedback loops open for various adaptations and updates as new paradigms and developments occur in its environment. Factors of change, *"exogenous"* meaning arising outside the area of TEL (in the majority are macro scale changes), and "*Endogenous" changes*, which are produced by tensions resulting from the different goals and capabilities of the stakeholder groups within TEL, are identified. Therefore, it is of paramount importance to have a methodology in place called *"observatory"* that will continuously provide *a "horizon scan" for new developments***,** in the wider macro context of the PESTLE drivers, as well as in the meso and micro education and technology fields. In order to keep the developed roadmaps dynamic and agile, their key drivers, uncertainty dimensions and assumptions need to also be fed into this *observatory function* that supports the co-innovation group's implementation and update process, including scanning for relevant developments in the wider contexts in which the roadmap is operating. Thus, the co-innovation group, in collaboration with a dedicated intelligent network, should regularly monitor the uncertainties associated with the future (the trends and signals identified via foresight projections) and continuously checking these against current realities, so that the co-innovation group can review and update its roadmaps as necessary. These will be used to determine which of the projected context scenarios are being realised and hence, reduce several alternative roadmaps to one roadmap for the near term future. They will also be used to modulate the *perceived* importance or affordance of the Roadmapping visions and proposed actions. This observatory was implemented under the TEL-*Map project* using the proposed *framework for analysis.* For newly emerging technologies brainstorming and selection of potential uses in TEL was required, as well as an analysis of the potential impact of the envisaged uses.

Coordinate innovative communities and managing contradictions

Furthermore, Engestrom tells us that "In different phases of the expansive learning process, contradictions may appear (a) as emerging latent primary contradictions within each and any of the modes of the activity system, b) as openly manifest secondary contradictions between two or more nodes (e.g. between a new object and an old tool), (c) as tertiary contradictions between the newly established mode of activity and remnants of the previous mode of activity, or d) as external quaternary contradictions between the newly reorganized activity and its neighbouring activity systems" (Engeström & Sannino 2010, p.7), see figure 53. Although, the initial cartography and the observatory activities will capture some of these contradictions in terms of a) clustering and bringing people together with similar or complementary objectives and approaches during the formation of the co-innovation group; and b) identifying tensions, drivers, trends, weak-signals, or other influential factors and incorporate them in the roadmapping context scenarios, a more in-depth analysis of their possible effects in the roadmapping plans need to be made. "Conflicts, dilemmas, disturbances and local innovations may be analysed as manifestos of contradictions…. These types of contradictions relate to 5th action of the expansive learning of "implementing the model" in practical ways" (Engeström & Sannino 2010, p.7), see figure 53. For example, when tacit knowledge is becoming explicit and combined via SECI, a new internalised understanding is achieved that might affect the previous aspects of the roadmapping process and the roadmaps themselves. For example, trigger the formation of new activity systems, change perceptions or assumptions in context scenarios and/or visions, change the operationalization of the roadmaps and the action plans, and affect their wider adoption by the stakeholder community.

In the past, many originally very promising technologies have run into a "last mile" problem, essentially failing to convince either the actors involved in the supply-delivery innovation chains or the wide majority of users of their benefits. Technology adoption is about making technology available (a delivery process) and most importantly about people, their expectations, and what they imagine and then learn about what a technology can do (a social process). Often users' response to new technologies undergoes a stagnation or disillusionment stage (HypeCycle), before it picks up again. Failing to identify this development at an early stage - and to deal with the reasons behind it - can have a seriously negative impact. In reality, technology adoption conforms to more complex patterns and is subject to the influence of very diverse factors. The issue of uncertainties in user responses and acceptance of emerging technologies are often ignored, and in reality the future visions simply concentrate on technological potential and supplier's deployment processes. Ron Adner in his recently published book, The Wide Lens (Adner 2012) proposes a useful model which was adopted in 'Dynamic Roadmapping'. Essentially, he points to the dependencies an innovator will often have on co-innovators and also to the value chain suppliers and intermediaries. He suggests mapping out these players and their interdependencies in a 'value blueprint'. The key questions are a) who else needs to be able to co-innovate with you before your value proposition reach your users? And b) who else needs to be able to adopt your value propositions before they reach the end users? Sections 2.2.7 (pp.63-66), describe this approach and workshop 5 (section 6.5.5) explains how it was implemented in the case study.

In this perspective, the roadmap is viewed as an activity system which comprise of several other activity systems. Similarly, the roadmap is viewed as a super innovation chain system that is comprised of sub innovation chains systems.

Challenge C: How the knowledge created can be spiralled and communicated within the boundaries of individual, organisation and outside communities?

According to IPTS[10], the European Commission's Institute for Prospective Technological Studies reports that "the paradigm underpinning ICT-enabled innovation for learning entails a holistic transformational shift towards connecting learning organisations and processes (i.e. connecting the realities of learners' lives and their experience of school). It applies the four principles of social innovation, where innovation is conceived as open, collaborative, free and characterised as "with" those involved (and not innovation "to" or "for")" (Kampylis et al. 2012). Similarly HoTEL[11] project claims that innovation, particularly in the field of TEL, may take very different forms than the classic paradigm that moves from research through prototypes to massive commercial exploitation. In the field of TEL, innovation may frequently start in a classroom or in a community of practice, or may be the result of massive use of a technology not born for educational purpose. The road to success for a TEL innovation depends, to a large extent, on the possibility to be understood and supported by some categories of stakeholders that are not always the same (e.g. industrial investors, school leaders, publishers, policy makers, teachers' networks, student associations, consultants, et cetera) (Kamtsiou & Nascimbeni 2013), (Meiszner et al. 2014).

In this perspective, a participatory, systemic innovation model is needed in order to deal with the dynamics necessary for creating and implementing innovations in complex domains. This requires the simultaneous collaboration of different actors, who belong in different value networks, and who, through relational activities, produce innovations and support the adoption of these innovations, by sharing, externalise, modelling, extend, combine and internalise their tacit experiences and explicit knowledge. For example, the need to involve actors "outside the schools community" and to promote collaboration with "external research" (e.g. TEL researchers, standard experts), "industry players" (e.g. tools and software developers) and "policy makers" (e.g. curricula developers, ministries of education, funders) is critical and is depending on a complex stakeholders' ecosystem, which determines the schools' evolution. Thus, innovation in learning implies the need to consider not only innovation processes and their roadmaps, but also the significance of the interconnection of the actors involved in the processes of innovation.

[10] https://ec.europa.eu/jrc/en/institutes/ipts

[11] *HOTEL (HOlistic approach to Technology Enhanced Learning) is a Support action of the 7th Framework Programme which aims to design, develop and test a support model for innovation in the area of Technology Enhanced Learning.*www.hotel-project.eu.

Challenge B analysed this from the perspective of connecting the innovative communities based on their interconnecting activity systems. *Challenge C* considers how the knowledge is spiralling among the different innovative communities and who they are. Moreover, *the Adner model* for adoption is used in order to communicate the roadmapping activities and requirements across different actors involved in the roadmap's supply chain, as well as other intermediaries involved in its implementation.

In this section, the school sector is also used as an example in order to analyse the different communities involved in the systemic innovations.

TELMap and HoTEL projects identified four main genesis models that exist in the field of Technology Enhanced Learning (Kamtsiou & Nascimbeni 2013), (Meiszner et al. 2014).

First, a *technology and industry-led model*, in which technological innovations, which in most cases were not specifically designed for learning, are adopted in educational or informal learning applications, and in some cases led to large-scale adoption due to massive industrial and commercial investment. The case of tablets use within classrooms, but even more importantly in informal learning corresponds to this model. *The LMS and Content Management Systems are additional examples of industry led innovations.*

Second, a *research-led model*, in which a) new pedagogical theories are tested in experimental learning settings, which are created and monitored to check learning effectiveness, usability and other key features; or b) new learning technologies, tools, and software are developed within research TEL projects, either funded by national or European level research and development programmes. *For example, Professional Learning Environments (PLEs), competency models, federation repositories, Learning Design models and tools, etc.*

Third, a *practice-led model*, in which bottom up innovation is emerging from individuals or communities of teachers and learners that finds original ways of using technology to materialise new pedagogical ideas about learning and teaching and are able to demonstrate their effectiveness in new contexts of use. *New learning paradigms, such as flipping the classroom, connectivism approach to learning, rizhomatic learning, game-based learning, action-research approach to learning are some examples of the practice-led model* (Kamtsiou et al. 2014), (Millwood et al. 2013), (Nascimbeni & Kamtsiou 2014).

Fourth, *the policy-led innovation mode*l, materialised by the many national programmes launched since the 80s to diffuse ICT and its use in classrooms. These policies give support to one or the other of the existing three models, or a combination of those, without really establishing a different genesis model. Policies may become very relevant, on the contrary, in the subsequent steps of innovation life cycles, and notably adoption, scaling up and institutional exploitation. *Different funding programmes are developed in order to target these issues at EU and national levels.*

Each of these models of TEL innovation has some strength and some weaknesses. HoTEL project has identified some main problems, which affect and delay the adoption of TEL innovation processes. *First*, bottom-up micro-innovations related to the way innovative practices use technologies for learning are not taken into account by TEL research communities, although such bottom-up micro-innovations are playing an increasingly important role in the field. *Second*, there is a need to verify the impact of existing learning theories on ICT for learning practices in order to determine, whether this has actually led/is leading to innovation. The same is true for the results of TEL research projects and their expected impact, compared to the way the usability of these results is perceived in practice by the communities, who were intended to adopt them, such as schools. *Third*, the lack of a holistic approach in the field prevents the mainstreaming of TEL innovations: too often, there is a lot of time elapsed from a) the identification of technologies that need to be developed integrated and adopted in order to be used in a learning domain, b) the theoretical analysis of pedagogical implications, c) the piloting of such technologies and d) their trials with real users. Consequently, commercialisation by industry players takes so long that the technology itself becomes outdating.

An integration of approach is needed in order to integrate the experience and findings from all these different TEL innovative communities.

In the 'Dynamic Roadmapping' framework, the different roadmapping communities are connected via a *'co-innovation'* roadmapping group and its *'observatory'* group (see figure 57).

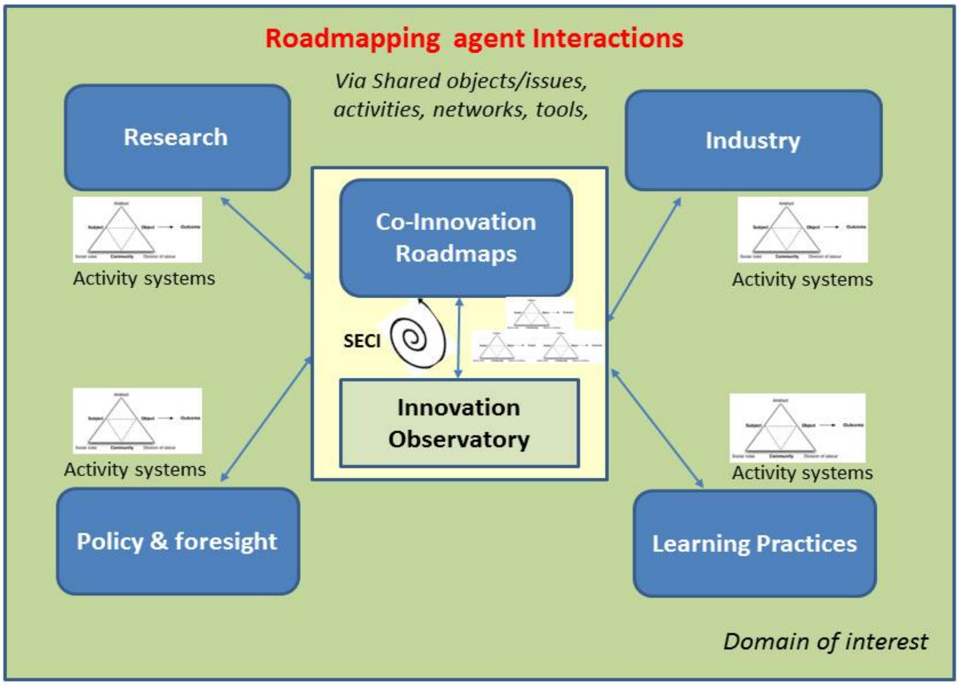


Figure 57. 'Dynamic Roadmapping' Model: Synergetic integration of different types of Roadmaps

As descried in challenge B, the *Activity Theory* is used in order to connect the different communities based on their shared issues, objectives, through common activities, via clusters/networks (co-innovation groups). As described in challenge A, the *SECI framework* is also used in order to provide a shared platform for the communities to share their various knowledge assets, while their individual knowledge is expressed and amplified by the SECI knowledge creation spiral. The information related to the roadmapping outputs of policy, research roadmaps, industry and practice roadmaps are codified and fed as intelligence to the ‘co-innovation’ group via the observatory. The ‘co-innovation’ group is formed from all the necessary co-innovators, adopters, decision makers and users which make up the ‘co-innovation’ ecosystem of the particular TEL setting or segment. These actors need to be identified, involved, agree on the innovations and their role in implementing them, and those who will be actively involved form a ‘co-innovation’ group. Their initial and later updated roadmaps and any related information needs of the ‘co-innovation’ group are fed to the policy and research communities and industry actors, again via the intelligence observatory. Thus, integrating in this way, foresight (Policy roadmaps) and research (Research and industry roadmaps) with the strategic planning of TEL stakeholders at their operational and innovation management plans (‘co-innovation’ roadmaps).

3.1.3 Putting the ‘Dynamic Roadmapping’ model into systems perspective.

In ‘Dynamic Roadmapping’ model, *the roadmap* is considered to be the *‘innovation system’***.** *This system (the roadmap)* is understood, modelled, shared, combined and transformed through the knowledge creation activities defined in the SECI framework, i.e. socialisation, externalisation, combination and internalisation. This innovation system is only partially understood in the beginning of its operation, since it is depended on various contextual factors from its environment, as well as on the actions and interactions of various communities, internal (e.g. within the co-innovation group) and external to the system in its transactional environment, which form their own activity systems. Thus, a system cannot exist without its environment, which is the context of the system. In ‘Dynamic Roadmapping’, the system is kept open and dynamic via an ongoing cartography and monitoring functions, which monitor and record changes that could impact the system, thus providing intelligence for its continuous adaptation to changing conditions in the environment.

Scenario development based on changes in transactional and contextual environments of the system.

In their chapter 2, pp. 17-29 of their book “Business Planning for Turbulent Times. New Methods for applying scenarios”, R. Ramirez, W. Selky, K. Van der Heijden (Ramírez et al. 2010) claim *that evolution is adaptive, not progressive*. Systems thinking is a good approach to deal with uncertainties via exploring different scenarios, especially in volatile environments. Ramirez and Selsky argue that people deal with turbulent times differently. People, who are able to adapt don’t see the environment as turbulent as opposed to people who find it difficult to adapt. Also, there will always be some groups that will try to keep the turbulence away. The authors agree with Wack's claim that scenarios are developed *not to predict the future but to affect the planning process for it.* It enables the innovators and policy makers to better understand the cause and effects, evidence and possible strategies related to turbulence. The authors also explain how the *causal textures theory* first developed by Emery and Trist (1965) cited by (Ramírez et al. 2010) influence the *contextual* and *transactional environments* of a system. *Casual texture* is defined as an *emergent property* of the whole field and concerns the behaviour of all systems within it (Ramírez et al. 2010). The causal texture of the field sets the conditions on how these systems, in our case the roadmaps and their environments transact. It is also one of the principles that underline the Future Search Conference adopted by the Dynamic Roadmapping model. It helps people plan for their future based on anticipated environmental changes and causal texture.

Emery and Trist (1965) cited by (Ramírez et al. 2010) have defined *4 types of causal texture* based on how organisations/systems in the field *(termed "1")* and their surrounding environment *(termed "2")* are linked. For example, in case of Dynamic roadmapping, "1" includes the co-innovation group, its roadmaps and all other TEL actors and their roadmaps in the field. While "2" is the environment that they operate. Emery and Trist have identified 4 possible links (L) between the system and its environment. These links *("L")* are called law types and are driven by logic that applies for a certain time period. The analysis of these links provides a good understanding of the behaviour of the system.

1. *L11* denotes links that remain internal to a system. For example if we consider the co-innovation group as a system, their roadmap is an internal roadmap, and the L11 denotes the interrelationships (nodes and links in the roadmap, as well as the dependencies among the members of the co-innovation group).
2. *L12* links the system to its environment – system outputs, related to the planning function (for example, direct provision of products and services to others). This level includes collaborators and competitors. For example, how the co-innovation solutions are adopted.
3. *L21* links the environment to the system – for example, system inputs related to the roadmapping plans. These inputs usually are identified through a learning process. For example, through workshops the co-innovation group identifies and maps possible resources like talent, technological solutions, research, competencies, funding options, etc., that can be drawn from the domain. These also could include threats that might come from competitors or from the unwillingness of other actors to collaborate with the co-innovation group.
4. *L22* denotes links between elements in the environment itself, which occur independently of the system (macro level: interactions between systems in the wider environment, e.g. growing imbalances in global trade relationships, or PESTLE drivers that might affect the system like new legislation, financial crisis, disruptive technological innovations, etc.)

Transactional and contextual environments of a system

Transactional environment

The competitive and collaborative operations and relations of all actors in the field are defined by *L21 and L12* links. All these organisations and actors interact directly with the system. This formulates the *transactional environment* defined by the actions of the actors in it (Ramirez et al., 2010, p. 24). In case of Dynamic Roadmapping, its transactional environment comprises of all the co-innovators, suppliers, intermediaries, users, regulatory bodies, and anyone else, who will need to align their contributions for the roadmap's innovations to be adopted. These links are first captured by a dynamic cartography and then by the 'innovation blueprints' approaches.

During the co-innovation formation process, the system outputs and system inputs (L12, L21) are the results of the strategic planning of its members and their activity systems. As the co-innovation network forms, it becomes new a "system" in the transactional environment, which last as long as the Roadmapping activity and implementation of its actions goes on. In addition, taking an organization as the system in focus, its relationships with other groups and networks, for that organization are part of its transactional environment. However, taking the *co-innovation roadmapping network as a single (meta-) system*, the relationships and transactions between its members organisations are internal to that network (1,1) and hence its roadmap provides internal coordination (1,1). The transactional environment of the co-innovation roadmapping group is made up of the transactional environments of each its members in so far as they relate to their shared roadmapping activity. Thus, a roadmap can also be seen as defining the boundaries of the co-innovation roadmapping network's transactional environment (L1,2 & L2,1).

Contextual environment

The contextual environment is defined by L22 links, expressed not as agent actions, but in terms of macro factors, which cannot be influenced by the individual actors. L22 links are relevant to all systems in the field, since they are describing the external environments the systems operate and which are outside their influence. In relatively stable times, the relationships between elements and other systems in the environment change only slowly, so not much attention need be paid to them. However in turbulent times, these relationships change constantly and hence demand significant attention.

The inside (the internal elements of a system) and the outside (the environment of that system) co-evolve in the sense that systems and their environments mutually influence each other, and they progress into the future together (Ramírez et al. 2010). Variables exist within each system, but also between inside and outside the system. The several interacting systems, their shared environments and the links that connects them together are defined as the field Ramirez et al., 2010 p.19 (Ramírez et al. 2010). Both the system and the environment (its context) are changing continuously, *therefore there is no such a thing a one future*.

In the case of 'Dynamic Roadmapping', L11, L12 and L21 links are first externalised and mapped via the ***cartography*** activities, which *captures the voice of innovative* communities, in order to map out their activities, relationships, offerings and contradictions of the individual actors in domain. The result is the transactional environment or *cartography domain map*. This provides an understanding of the existing systems, their history, and the different stakeholders perspectives. During this phase, the *activity theory* is also used in order to be able to understand conflicts and similarities among the existing systems and to group the actors, so that their L11, 12, 21 activities are matched as similar or collaborative.   The emerging relationships between these actors provide the candidates for the *co-innovation roadmapping network formation phase.* Conflicts are noted as weak signals to be monitored and analysed during the roadmapping process.

Desired scenarios are developed by the co-innovation group in order to describe the ideal state of the system in (L11, L12, and L21) and to develop a commonly agreed design (roadmaps).

Context scenarios are considered in 'Dynamic Roadmapping' to be the methods to assess the causal texture by considering how L22 forces in the contextual environment interact systemically to affect a set of transactional environment possibilities (L12, and L21).

The desired scenarios and their designs (roadmaps) are stress-tested using the *context scenarios* in order to understand how forces/drivers from the *contextual environments* (L22) could impact them in the future and also shape the new transactional environments of the co-innovation group.

Finally, during the dynamic implementation and monitoring phase, *an observatory system* provides new intelligence streams to the co-innovation roadmapping network, via scanning and interpretation of emerging events that could influence the L22 links. These change factors are monitored and analysed by using different methods such as Week Signals and cross impact analysis, Topic Mining, Social networking analysis, Delphi, surveys, interviews and focus groups. Thus, the observatory informs and enables a dynamic update of the co-innovation's strategic Roadmapping plans, as well as provides intelligence for a new mapping and understanding of the future L22 links (Ramírez et al. 2010). Especially, in turbulent times where L22 links are very unstable and unpredictable, this scenario planning and dynamic monitoring of the environment is vital. note: the co-innovation roadmapping network could also be formed using a more top-down approach, when turbulence in the system calls for domain actors to come together to collaborate in order to define a set of values that will form "inter-organizational islands arrangements that can keep turbulence outside (Ramirez et al., 2010, p. 23). The following schema (see Figure 58) depicts a generic model of the positioning of the co-innovation group in its transactional and contextual environments. The transactional environment is that part of the environment that the system (in our case a co-innovation group) interacts with and can influence. The contextual environment is the remaining environment that is beyond the system's influence, but which can still make an impact on it. The transactional environment of the co-innovation group is effectively *the sum of the transactional environments of its members*. The uncertainty arrows in the diagram that impact on the co-innovation group represent the sources of the group's projected context scenarios. The desired futures scenarios represent the intersection of the co-innovation group members' visions. The co-innovation group has also to articulate the internal and external tensions that will have to resolve or accommodate.

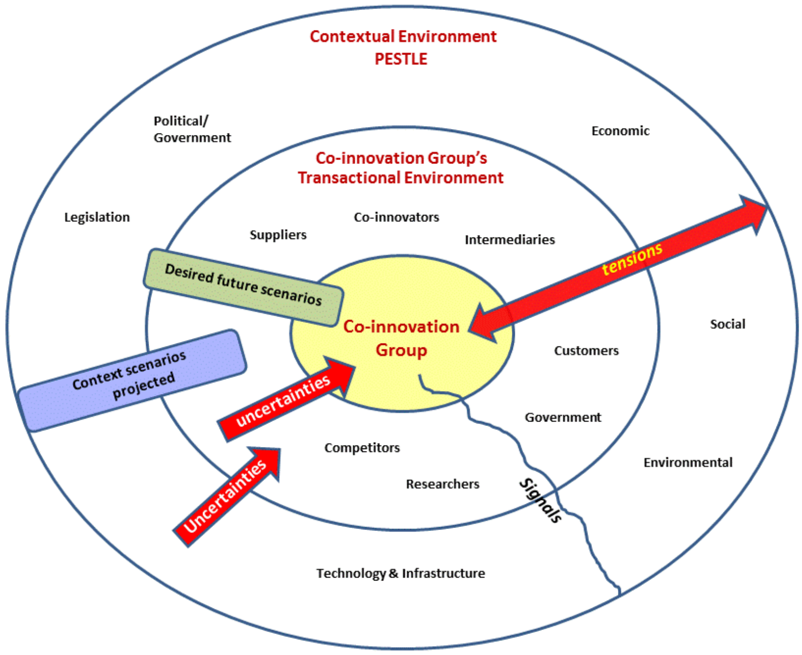


Figure 58.   Co-innovation Group situated within its Contextual and Transactional Environments

Illustrative example of contextual and transactional environments in TEL

This section provides some examples as an illustration of the above analysis which is derived from the work in TEL-Map in the education domain.

When, we focus on a complex domain such as education, it becomes essential to understand both, the macro factors of changes related to the contextual environment and the differences in stakeholders' perspectives, if we are to produce meaningful and informed scenarios and roadmaps. In case of TEL domain, a system could be either a TEL actor, when operating independently, or the co-innovation group acting as a new meta-system.   With respect to the achievements of their shared goals, the transactional environment of the co-innovation group (L12, L21) is greater than that of any of its members; hence they can act more powerfully together than in isolation. This is extremely important for systemic innovations, complex and volatile domains where an organisation is not able to create and implement innovations by acting alone.

Contextual environment of co-innovation group

At the *macro level* of scale, these perspectives come to bear in the political and macro-economic processes and are generally considered as an aggregated *macro contextual environment "PESTLE"* (Political, Economic, Social, Technical, Legislation, and Environmental). The issues in the contextual environment are external contexts and they are not within the sphere of influence of the co-innovation roadmapping network, but they are drivers, forces, factors that can either hinder or support their visions.

Key areas for analysis include:

Political: Policy-makers may have more or less appetite for intervention in education, but it seems likely that the politics of education, especially schools, will retain its profile in the public eye. Main focus is on changes in the “balance of aims” of education (socialisation, individualisation, and professionalization) in the 21st century and implications for the education system arising from continued efforts to build a peaceful and prosperous Europe through cohesiveness and inclusion.

Economic: Trends in globalisation and the emergence of new centres of economic power have been apparent for some time but the recent near-collapse of the global financial institutions has injected both uncertainty and new imperatives in managing public and private sector balance sheets. TEL developments include sever cuts in educational funding of learning organisations and in educational research.

Social: Changes in society at large that influence Education and Training should be considered, recognising that many changes display strong socio-political coupling. Presently visible trends in societal demands, which could give rise to demand for new TEL services, include:

- Expectations of openness and transparency in public institutions
- Expectations of free access to information of diverse kind and provenance from the authoritative to the opinion of individuals
- Emphasis on participative and democratic ideals of open source software and open content
- Changes in the status of formal authority over the “wisdom of crowds” and postmodern “anything goes”
- Changes in the nature of human relationships and their spatial distribution from local community to worldwide cyber society
- Greater prominence of creative and knowledge work in contrast to traditional manufacturing work.

Technological: ICT has changed most aspects of society and shaped the way people think about their relationship to the rest of society and its institutions. With particular reference to TEL, the following are observed:

- Changes with respect to the teaching/learning process – especially in relation to the use of ICT and Web 2.0 technologies – if we are to exploit TEL for flexibility, autonomy, and differential rates of learning progress for different groups of learners.

- New opportunities for global-scale approaches to TEL in both formal and informal learning;
- Change in LET to provide truly mobile learning in terms of learning design, devices, and content (e.g. use learning widgets, games for mobile devices, etc.)
- Trends in personal ownership of technology outside LET - such as personal blogs, email, web storage, physical devices – disrupting existing patterns of provision. For example an anticipation that there is an appetite among the learners to build their own Personal Learning Environments which are responsive, user centred and open to integrate with systems and content that the learners are using in their personal life rather than contentment with purely institutionally-provided and proprietary forms of ICT.

Legal: The legal domain could be seen as an instrument used by the political actors. However, related to ICT and TEL, two legal themes are of vital importance:

- Privacy: When more and more interactions are online, issues as Preventing harm, Integrity of Personal Information, Notice, Security Safeguards, Collection Limitations, Access and Correction, Uses of Personal Information, Accountability, and Choice is of importance to the user. (These “principles" are from the "Privacy Framework" of APEC, the premier forum for facilitating economic growth, cooperation, trade and investment in the Asia-Pacific region.)
- Intellectual Property: Issues on IP Rights have been a major theme for the TEL community now for a decade, e.g., playing a pivotal role in discussion on sustainability of learning resource repositories.

Environmental: The consequences of change in our place as organisms in the environment of planet Earth and the role of TEL as a viable future is undeniable yet highly uncertain. This is an area with a great deal of active strategic planning that can inform TEL observatory. Two related themes that are likely to influence the nature of the demand for learning/training and the nature of the agencies and business involved in delivering it:

- The direct effects of climate change and our current attempts to mitigate it with new forms of energy production and reduction in energy use.
- Population growth and migration and measures to avoid unsustainable growth or unmanageable migration.

These macro driving forces for change in the education and training systems can be projected into the future with varying degrees of confidence and uncertainty. These are explored using scenario planning to handle these through the development of multiple plausible ‘context scenarios’ against which the ‘desirable future scenarios’, and the roadmaps for achieving them, can be developed and continuously evaluated and adjusted as necessary (Kamtsiou 2013).

Transactional environment of the co-innovation group

As we move to *meso* and *micro* scales, there is a greater focus on *Education and Training (E&T)* domain and a consequentially greater influence is possible by the co-innovation group. The *TEL transactional environment* is the immediate operational environment that consists of the actors, organisations at meso scales and solutions and technologies at micro scales that need to be aligned and coordinated for the successful adoption of the co-innovation group's roadmaps.

At m*eso-scale, aspects of the organisation of education and training systems are considered* and the relationships between the component organisations involved in the delivery of learning, education and training. These may be: public bodies or private commercial concerns; small, numerous or large; operating across national boundaries or regionally; involved in the delivery or regulation/management of education and training (Kamtsiou 2013). This also reflects the requirements of TEL stakeholders, and their respective organizations such as schools, higher education institutions, firms, etc. This analysis involves;

a) *The Organisation of the Education and Training System*

By "organisation", it is understood the component parts and their relationships that comprise the totality of the "education and training system". Within this 'ecosystem' are both top-down, more or less government directed, agencies as well as autonomous institutions subject to more or less regulation and more or less dependent on other institutions or agencies for their survival. Each agency or institution displays its own structure within this system. Examples of the ways in which the context of Education & Training has shaped the agencies in their delivery of policy, and which consequently influence the spectrum of futures for TEL include:

- Changes required in assessment and certification methods in a world in which information and learning sources are much more abundant than in the past. Moreover learning achievements should be recognised and assessed independently from the method and place of acquisition – taking into consideration the requirements of the European Qualification Framework;

- Changes required by policy-makers' attempts to "balance the aims of education" for the 21st century (socialisation vs. individualisation vs. preparation for a profession), raising questions as to what kinds of innovations are needed to support these through flexible learning places, supporting better education, competency development and employability.

- Changes required developing a renewed effectiveness of education and lifelong learning as instruments of social mobility, cohesiveness and inclusion in the European society;

Challenges at the level of the individual institution arise from all of these global, social and technological changes. In higher education for example, (Siemens & Tittenberger 2009) have identified a number of "fault lines" where tensions are building up forcing universities to "rebalance”: Education/business; Accreditation/reputation; Transformation/utility; Research/responding; Formal/informal; Open/Closed; Expert/Amateur; Hierarchy/Network and Command/Foster; Pace/Depth; and Epistemology/Ontology. Similar “fault lines” may also be identified in primary and secondary education and training.

In addition, the institutional level we observe:

- Changes required in strategies to generate and maintain the motivation of different groups/classes of learners in different learning contexts, allowing them the develop their identity as learners;

- Changes in TEL from a B2B market to a consumer-oriented market with offerings to end-users. This is driven by Web 2.0 / semantic technologies, but also by an up-scaling of social networks, mobile apps, new business models coming from widget technology etc. This could be a critical challenge for established institutions, as new providers meet the needs of consumers with alternative learning methods.

- New business models forcing both the disaggregation of business and learning information systems into component services and subsequent agile re-integration;

- The changes required to accommodate the evolving demographics of an aging society, migration, marginalised youth, and the increasing importance of Life Long Learning.

b) Emerging Learning Paradigms

As we move to more micro-scales in the changing *understanding of learning* and the *identification of emergent paradigms* will be an important area of activity for TEL and one where it is expected to find many reciprocal relationships with changes in technology and the uses people put it to. This includes changes in the ways people – teachers, learners and society in general - *understand the concept of learning* and hence how *new forms of learning* are likely to emerge. At *this micro level* the focus is also on new and emerging technologies around TEL that can be used for producing TEL solutions and new ways of supporting teaching and learning processes. Examples of such technologies are semantic web technologies, neural networks, AI, intelligent agents, social software, video and mobile technologies, cloud computing, data analytics, etc. The potential of such technologies to disrupt existing patterns of learning provision should also be examined as well as their importance to informal learning (Kamtsiou 2013).

New forms of learning supported by TEL can only arise from changes in the way learning is understood. New understandings are expressed in new ways of doing things and from these we derive the abstraction of a learning paradigm. Whereas TEL has often been conceived as new methods of support for established forms of learning, we should seek the strategic advantage of applying TEL to emergent forms. Emerging learning paradigms needs to be decomposed in order to identify changes in: a) the kinds of activities and environments within which learning is intended to occur; b) what is valued as learning by different stakeholders; c) the kinds of activities and environments of assessment and the ways achievement is expressed. These are distinct considerations that arise from a socio-political understanding of the purpose of the educational system and its institutions; they are specifically about learning.

Moreover, among changes in the kinds of learning activities and environments, it is expected to find a rich spectrum of roles for TEL, but a recurrent theme will probably be that society demands new learning paradigms and applied technologies that support all aspects of learning (including unlearning, to handle change in the world) and which are socially inclusive. There is likely to be a desire to support forms of learning that are both individual and collaborative, both cognitive and situated (what have I learned? What can I use it for? How can I or my team apply and extend it? We expect there to be a trend towards collaborative design of ICT in order to support the management and delivery of LET. Trends in what is valued as learning are more subtle because they are less observable than the activities and environments of learning. What is valued as learning is becoming more diverse in modern times. One aspect of diversity is *consideration of utility*. For example, in a knowledge economy compared to a manufacturing economy - we have come to value information literacy. With the spread of Open Educational Resources, we see more statements about the value of sharing knowledge, but not yet matched by institutional practices. We expect there to be discrepancies between the statements and observed behaviour of some stakeholders, for example employers who select employees using traditional measures of academic performance - yet value employees based on their autonomy and problem-solving ability. The kinds of activities and environments of assessment forms the final part of this 'trinity', inseparable but distinct. We expect that some stakeholders will be anticipating new business models and forms of organisation of the education system where assessment and delivery of learning are more clearly separated. We also expect that there will be continued interest in the accreditation of prior experiential learning and growing speculation on new models for work-based or simulation-based assessment tasks and environments. These may be identified as promising areas for TEL innovation as educational institutions seek to extend their student base and reduce costs. Will these innovations make assessment approaches where the context, content and format of an assessment is negotiated become a tractable proposition? How comfortable will different stakeholders are with such an approach?

In addition, the effect on TEL roadmaps by vendors who are developing technologies around TEL which have potential to be re-used in TEL domain should be considered by the co-innovation group. An example of two-generation rapid take-up is gesture-based interaction. The first generation is the Apple iPhone and Microsoft Surface. Ideas for the next generation of gesture-based innovations is now being promoted; it involves moving from tangible surfaces (as in the iPhone), to virtual surfaces (as in the air-based interfaces shown by MIT's Pattie Maes and Pranav Mistry, in their TED 2009 talk, where they described extending the gestural approach until it has the potential to become a "sixth sense": perhaps even a new form of learning).

3.1.4 Integration of SECI, activity theory and systems perspective.

This section summarises the research framework, and the theories and methodologies used in 'Dynamic Roadmapping' model from the perspective of systems thinking.

Systems thinking and foresight

(Saritas 2011) introduced a Systemic Foresight Methodology (SFM) which is grounded on the systems thinking ideas (see also Section 2.1.3). He describes 'systems thinking' "as an approach to deal with the complexity and uncertainty inherent in physical and social systems" (Saritas 2011, p. 5). SFM is based on the main principles of systems thinking, namely 'causality', 'holism', 'hierarchy' and 'continuity'. According to these principles, the system is more than the sum of each parts, thus understanding the interactions and interdependencies among the system's elements is very important; the behaviour of the system is not independent from its context; the system is continuously and dynamically transforming itself; the system can be both affected from and impact its wider contexts, i.e., wider environmental, socio-economic and political systems.

In the context of foresight, Saritas is based his SFM methodology in 3 main points (Saritas 2011).

- "The need to gain a rich understanding of existing systems and procedures, their history and possible futures
- The analysis of different stakeholder perspectives and their social relations in the system, which can affect and be affected by the process
- The impacts of formal and informal networks and procedures, which can be in favor or in conflict with other systems" (Saritas 2011, p. 9).

Figure 59 below depicts systemic foresight in the context of the Social, Technological, Economic, Environmental, Political, and Values (STEEPV) systems.

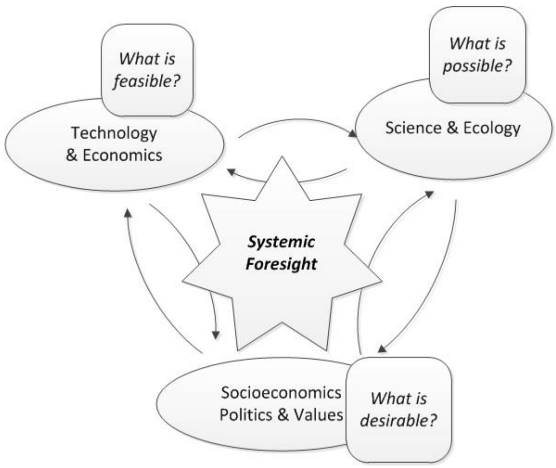


Figure 59. systemic foresight approach, adapted from (Saritas 2013), from figure 2, p10

(Saritas 2011) identified 5 phases related to SFM: (1) Systemic understanding (understanding and appreciating situations) (2) Systems synthesis and modelling (synthesising input into models), (3) Systemic analysis and selection (analysing alternative futures and prioritising them), (4) Systemic transformation (establishing the links between the desired future and the present), and (5) Systemic action (informing present day decisions)" (see Figure 60).

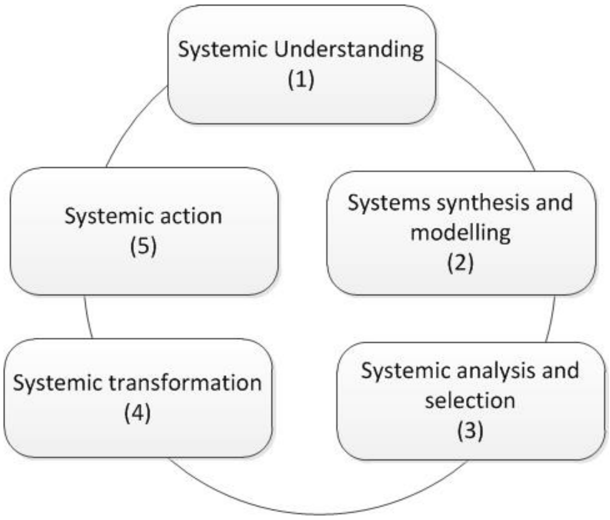


Figure 60: SFM process adapted from (Saritas 2011), from figure 3, p.14.

These five phases, (Saritas 2011) calls mental acts, comprise a learning system, which shows how different complex systems such as human and social systems, industrial and sectorial systems, are understood, modelled, approached and mediated in specific contexts in order to achieve systemic innovations and change. This approach regards the foresight activity as a 'systems inquiry', therefore, the system cannot be overly specified in the beginning of the foresight exercise, but it emerges during the system's operation.

In 'Dynamic Roadmapping' context, the SFM framework is adapted in order to put 'Dynamic Roadmapping' in the context of systemic innovations and systemic change. The conceptual model depicted in Figure 61, provides a holistic systemic innovation framework which integrates foresight, roadmapping, and innovation management approaches. This is an iterative process with feedback loops among the various processes.

Initial systemic understanding activities aim to gain a first *shared* understanding of the topics, activity systems, and influencing factors as independent systems in their own contexts. This is primarily achieved by scanning and capturing the voices of the different communities in research, industry, policy and practice. A bottom-up 'Cartography' is performed as an observatory function, which constructs an initial domain map. This cartography helps to bring together innovative communities that share complementary motives and visions, which will form the co-innovation group. The different activity systems in the domain are also identified and mapped (CHAT). In order to ensure that all necessary stakeholders are included in the co-innovation group, the ARE-IN principles from 'Future Search' methodology (Emery & Purser 1996) are also used.

Increased Shared systemic understanding activities aim to catalogue, connect, contrast, model and analyse the positions, concepts, factors, and tensions, among the activity systems. Thus providing *a shared understanding* of the issues involved. The co-innovation group, through socialisation and dialoguing (SECI) externalise and maps the initial positions of the different activity systems. CHAT theory is used in order to identify secondary contradictions and model them in the form of tensions in the domain. This results in an updated cartography of the domain.

Systems synthesis, selection and modelling activities aim to negotiate the positions identified from the previous activities and synthesise the input into conceptual models in the form of desired future scenarios (visions) for the area. The previously identified contradictions and tensions in the updated cartography are also driving the selection negotiation and modelling of the innovative communities positions in this stage. The individual visions of the innovative communities in the co-innovation group are externalised and combined in common visionary frameworks (SECI externalisation, combination activities).

Systems analysis and roadmap development selects, negotiates, and analyse the initial models of the future visions and 'prioritise' them in the form of agreed roadmaps. SECI is used in order to combine the roadmap concepts (what is needed to be developed) and through reflection to link them in specific visual designs (how to be developed).

Contextual systemic understanding of multiple futures activities aim to use *scenario workshops* as a foresight method, in order understand the external uncertainty factors, which could impact the systems (initial roadmaps, and visions) and model them in different context scenarios. SECI is use in order to combine the different factors and analyse and reflect on their possible impact in the innovation systems, thus combining the what (explicit combined factors) with the how (implicit impact).

Systemic transformation activities establish the relationship between the roadmaps and the future scenarios. Foresight methodologies are used to stress-test and play out the roadmaps in each context scenario in order to develop different development path-ways for each roadmap. They also determine the pathways to be implemented in the short term, which are related to the most likely future emerging scenario. SECI is used in order to combine the different elements in the context scenarios and assess and reflect on their impact in the roadmaps.

Systemic action and increased systemic understanding activities aim to implement the action plans in the roadmap *(How to, who)*. The Adner's model is used in order to map the resistance of different actors involved in the implementation of plans in order to inform decisions related to change and adoption (Who is needed to be aligned and coordinated?). These initial roadmaps are constantly going under monitoring and updating via the dynamic cartography. SECI is used to internalise the plans through action and to disseminate then in the relevant stakeholders. The new external contradictions are mapped using CHAT and the cartography is updated. During the systemic action, the systems (roadmaps) are dynamically updated and monitored. This dynamic implementation of the roadmaps might require new skills and competences, thus the enhancement of the co-innovation group. In addition, new events might impact or change the contexts of the roadmaps. The observatory function will continuously monitor this context and provide alerts to the co-innovation group.

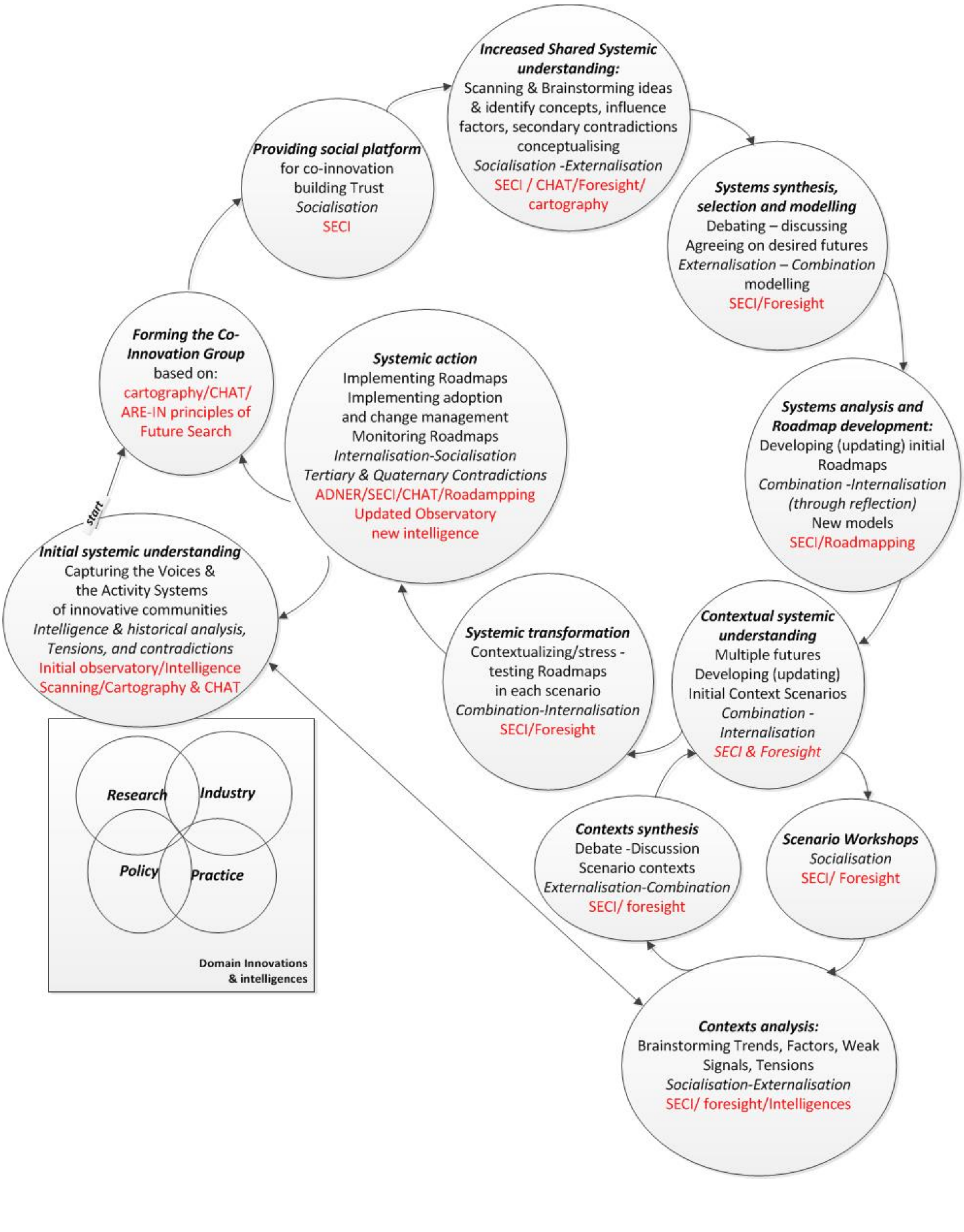


Figure 61: Theoretical framework or 'Dynamic Roadmapping' in the context of systems thinking.

3.1.5 Integration of Foresight, Roadmapping and Change Management

Figures 62 and 63 illustrate how Foresight, Roadmapping and Change Management approaches are brought together in the 'Dynamic Roadmapping conceptual model, in order to develop, implement and manage systemic innovations. These different approaches have been *integrated via an observatory function* which creates the necessary feedback loops for keeping the roadmapping process *alive and agile*.

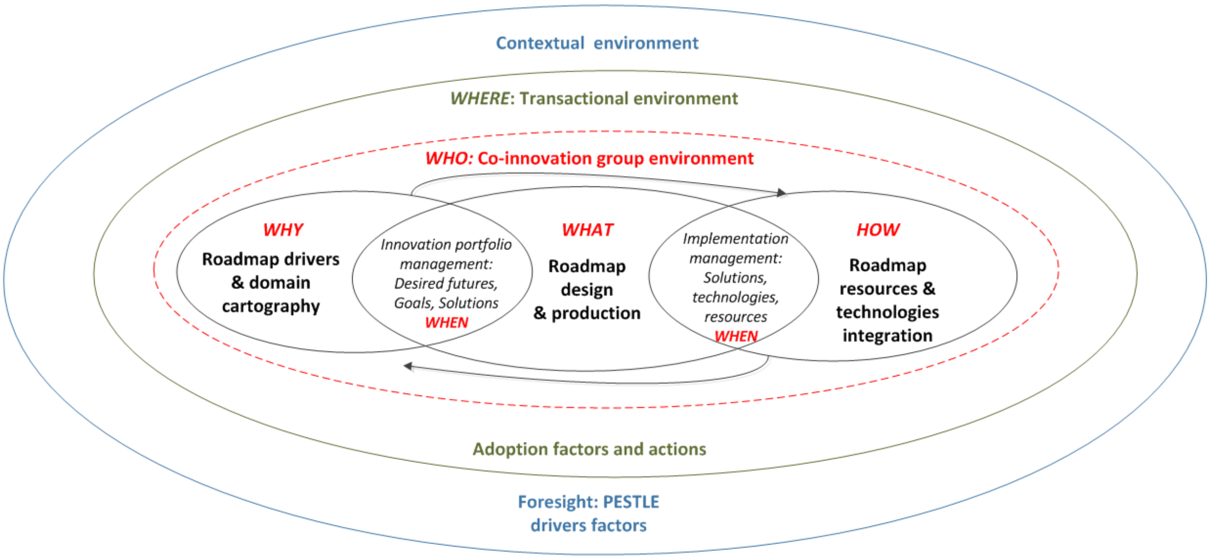


Figure 62. 'Dynamic Roadmapping' approach: integration of foresight, adoption and roadmapping

The co-innovation group's contextual and transactional environments

Under 'Dynamic Roadmapping', the three different environments a) *co-innovation group, b) transactional and c) contextual (*depicted in figure 62) are mapped to each approach respectively, i.e., *a) roadmapping, b)change management , and c) foresight (*depicted in figure 63) and are sub-sets of each other. The two way feedback between the observatory and the co-innovation group is what enables the dynamic implementation and revision of the roadmaps.

(Ramírez et al. 2010) division of a system's environment into transactional and contextual environments was adopted from their book Business Planning for Turbulent Times, chapter 2, of Emery and Trist's (please also refer to section: 3.1.3).

Figure 62, illustrates the positioning of the co-innovation group in its transactional and contextual environments. The *transactional environment* is that part of the environment that the system (in our case a co-innovation group) interacts with and can influence. The transactional environment is the immediate environment that the co-innovation group is operating in, and it is within their immediate sphere of influence. It is effectively the sum of the transactional environments of its members. The *contextual environment* is the remaining environment that is beyond the system's (co-innovation value network) influence, but which can still make an impact on it. The dashed line in figure 62, the boundary between the co-innovation group and the transactional environment indicates that it is permeable as new participants from the transactional environment may join the group or members of the group leave. The flow of information from the contextual environment via an observatory, together with two-way feedback between the transactional environment and the co-innovation group, is what enables the dynamic and adaptive implementation and updating of the roadmaps, especially in turbulent times.

Developing and implementing systemic innovations demands the full range of skills, methods, and intelligences that the three approaches of foresight, roadmapping and change management bring. These approaches are all brought together in an observatory that can then scan and maintain information about the signals, trends and uncertainties related to each approach (see Figure 63 below).

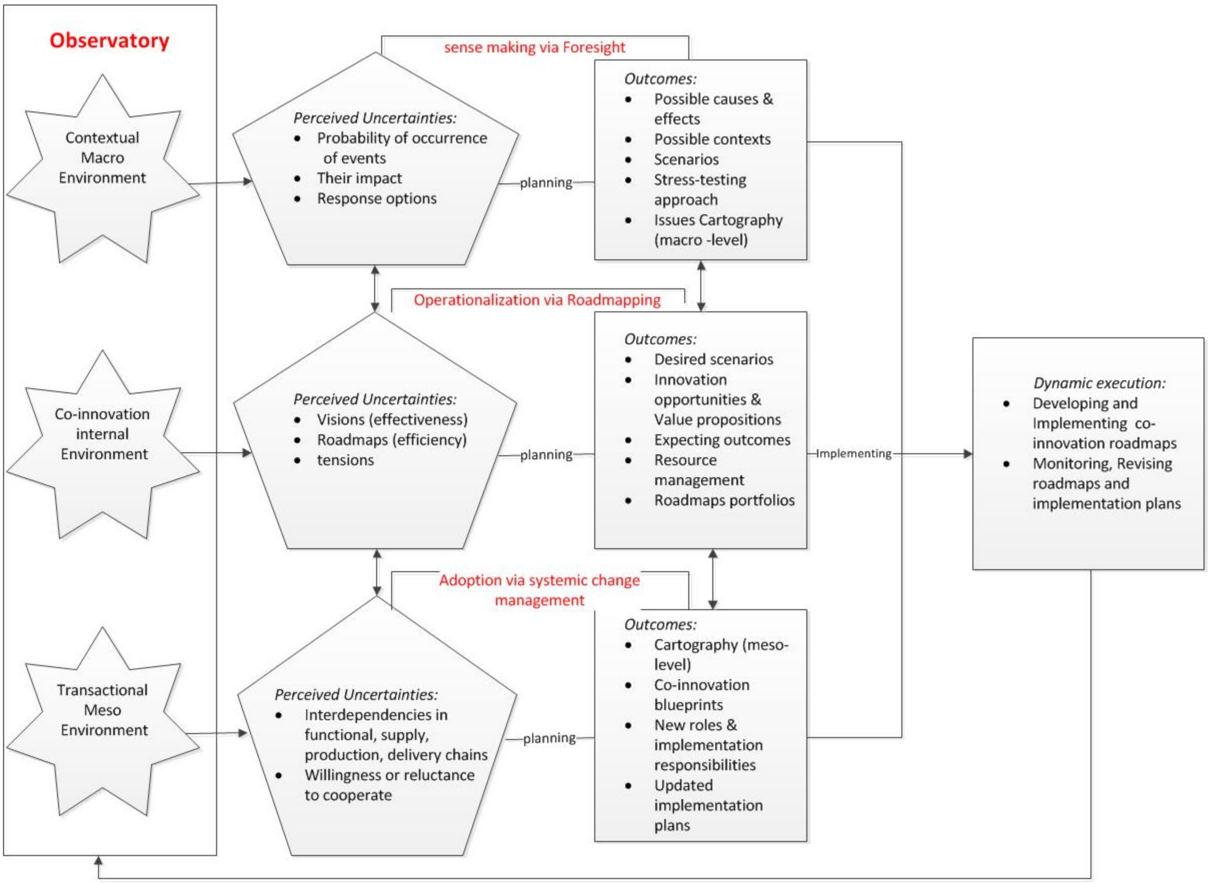


Figure 63: Integration of Foresight, Roadmapping and Change Management Viewpoints model via an observatory

Under Foresight, the uncertainties relating to the *contextual environment* of the co-innovation group and to the relevant PESTLE drivers are identified. At this macro level, these perspectives come to bear in the political and macro-economic processes and represent an aggregated *macro contextual environment*. The events in this wider contextual environment are not within the sphere of influence of the Roadmapping groups, but they include important drivers, trends and other factors that can be viewed as opportunities or threats towards the implementation of their desired futures and roadmaps. The possible causes and effects of these uncertainties are captured in the form of context scenarios, which in one way or another will influence the implementation of the roadmaps. Foresight methods such as Delphi are also used in order to capture weal signals and assess their impact in the co-innovation plans. These foresight activities are part of an observatory function, which is responsible for developing and updating cartography *of issues, topics, signs, change factors, etc.* that represents the macro level PESTLE changes that can impact the transactional environment of the co-innovation group. It provides different intelligence streams to the co-innovation group, during their development and implementation of their roadmaps. This is a two way process. The co-innovation group also passes its key drivers, context uncertainty dimensions and assumptions to the observatory, in order for it to then to scan for weak signals and changes in the contextual environments and to alert the group of those that could potentially impact its roadmap implementation activities. The capturing of these uncertainties is a continuous process that allows the co-innovation group to a) receive alerts about relevant signals and changes, b) update its context scenarios, and c) stress-test their roadmaps against the updated scenarios and adapt them as needed. As we move from the macro to meso and micro scales, there is a greater focus on the domain of action and a consequentially greater influence is possible by the co-innovation group.

Under Roadmapping, the co-innovation group's desired futures and action plans (roadmaps) are developed and stress-tested. At this stage, a *normative approach* to scenario planning is applied. Although the exploratory scenario planning (context scenarios) approach has been widely used in order to deal with uncertainties about the operating context, it usually pays little attention to the process of developing a desired future, let alone one that is commonly agreed across a diverse group of stakeholders. In the 'Dynamic Roadmapping' approach, these *desired future scenarios (normative visions for the future)* are developed by the co-innovation group and then they are stress-tested against each of the context scenarios (plausible futures for the wider context in which the co-innovation group will be working). The desired future scenarios illustrate the visions of the co-innovation group and the underlying assumptions on their usefulness. The roadmaps align the actions and the resources needed to realise the desired futures. The co-innovation group uses a *Future Search Conference* (Emery & Purser 1996), (Weisbord & Janoff 2000) and *online consultations*, in order to establish a strong desired future that integrates participants' existing visions and aspirations into a common visionary framework, as a foundation for their commitment to work together in order to deliver their shared desired futures. In fact, the co-innovation group, through imagining, describing and publicly sharing their desired future, creates a powerful way for them to influence their domain. Both the perceived usefulness of the desired future (effectiveness aspect: why they are desired? are we aiming at the right goals?) and its full realisation (the roadmaps perceived efficiency: are we using the right processes to realise the desired futures) will need to be negotiated more widely with other domain players. The *cartography of the co-innovation's transactional environment* developed under the change management approach will provide a good understanding of the key actors and their aspirations, their areas of collaboration and competition, and it will help to identify both alignments and possible tensions within the domain. Based on this analysis, *a bottom-up shared perspective* is negotiated by the co-innovation group, in turn enabling an evolving *meso level co-innovation roadmap* and *aligned internal micro level roadmaps to be developed*. The most promising innovation opportunities and value propositions are identified, and *a portfolio of design solutions* (see Figure 62) and *roadmaps* are developed at both strategic, production and operational levels *(implementation management (see Figure 62).*

Under Change Management (co-innovation's group transactional environment), the uncertainties related to the motives, approaches, visions, roles, actions, goals, networks, and proposed solutions of the different actors in the domain are captured and mapped by the observatory in the form of *Conceptual and Positional Cartography (meso level).* Methodologies used during this stage include, Social Networking Analysis; industry state of play; bibliometric; analysis of research projects; mining the blogosphere, capturing the voices of innovative communities' events such as workshops, interviews, surveys, etc. *This first mapping* of the co-innovation's group transactional environment in terms of the key players in the domain is of paramount importance in order to provide intelligence that would facilitate *the enhancement of the co-innovation group* with innovation communities that have similar goals and complementary resources and skills. After the roadmaps are developed, *a second mapping* is taking place in order to capture a new a set of uncertainties, related to the roadmaps' implementation, which include the willingness of the identified actors to collaborate in practice and coordinate their activities. The players, their roles and their dependencies are also mapped out. This mapping represents the transactional environment of the co-innovation group in terms of the interlinked innovation chains and value chains of innovators, suppliers, intermediaries and users mapped as an *'innovation value network'*. The aim is to identify all the sub-systems of players involved in the development and implementation of the *roadmap's designed solutions (see Figure 62)*, which represent the functional logic of the 'systemic innovations chains'. A methodology that integrates all these subsystems on both supply and demand sides is needed for the strategic implementation of the roadmap. To deal with this uncertainty, the *Adner's model of value blueprints* is adopted for managing the successful implementation and adoption of innovations (Adner 2012). Using this approach, the co-innovation group creates co-innovation 'value blueprints' for each design solution in the roadmap. Each of the actors that creates and adds value to the development, implementation and provision of the design solution is identified in a value blueprint, in which their willingness to participate is simplified and represented as a green, yellow or red traffic light against each player. In Adner's approach, these indicate respectively whether a key co-innovator will benefit from the innovation and is ready to go, will neither benefit nor lose and so is in an uncertain state, or will lose out from the innovation and is therefore unwilling to participate. It is a necessary, if not sufficient, condition for the innovation to succeed that the traffic lights for all the key players be turned to green. This typically requires an adjustment of the designs to redress their losing position, or a redesign so that they are no longer a key to success. Such mapping represents the transactional environment, which is the immediate environment that the co-innovation group is operating in, and is within their immediate sphere of influence.

Monitoring Inputs via an Observatory: Stress-Testing

As mentioned above, it is important to 'stress-test' roadmaps at each stage in their development. 'Dynamic Roadmapping' adopted the techniques based upon the four-field scenario approach of a 2x2 matrix (see workshop 1: section 6.5.1, workshop 2: section 6.5.2: 6.5.5). Key drivers in the wider operating context that judged to have a high potential impact on realising the innovations in the roadmaps, but whose outcome is highly uncertain are reduced to two 'tensions' or 'axes of uncertainty'. These tensions are used to create the 2x2 matrix, from which four scenarios are created to sketch out what the world would be like in each possible future. Influential trends, in which the group has reasonably high confidence, form a common backdrop to all the scenarios. The initial draft roadmap is then re-considered in the light of placing it in each of the four possible scenarios and for each in turn asking: What changes might be needed to the roadmap? Would roadmap require new or alternative activities? Does it create an alternative fork in the roadmap? And what would be the signs to watch out for that would indicate that the world is moving in the direction of this scenario?

3.2 'Dynamic Roadmapping' Stages

The 'Dynamic Roadmapping' process framework has three (3) main stages:

1. Initiation stage: This involves a) forming the co-innovation group, b) setting up the intelligence network and the observatory, c) drawing up an initial cartography of the domain, and d) activating the 'Dynamic Roadmapping' processes.

2. Development stage: This stage involves the development of co-innovation initial roadmaps, their contexts and innovation blueprints; stress-test them and further develop their first-cut roadmap/s against the context scenarios and gap analysis.

3. Dynamic implementation and adoption stage: Starting the co-innovation group's implementation of the short term part of their roadmaps; and later the roadmaps are monitoring and updating using the dynamic feedback from the observatory in the form of alerts and gap analysis reports; based on this analysis the co-innovation roadmaps and the co-innovation blueprints are continuously updated.

Strategic and Operational parts of Dynamic Roadmapping.

The roadmapping process consists of main two parts strategic and operational. The strategic part relates to the future innovation activities of a community of practice in terms of effectively agree and commit themselves to a shared vision and then, collaboratively develop concrete goals and action plans for achieving this vision. The operational part relates to the efficiency dimensions of achieving those plans and to the dynamic adjustment of the planned actions in order to align them with future surprises.

3.3 'Dynamic Roadmapping' processes

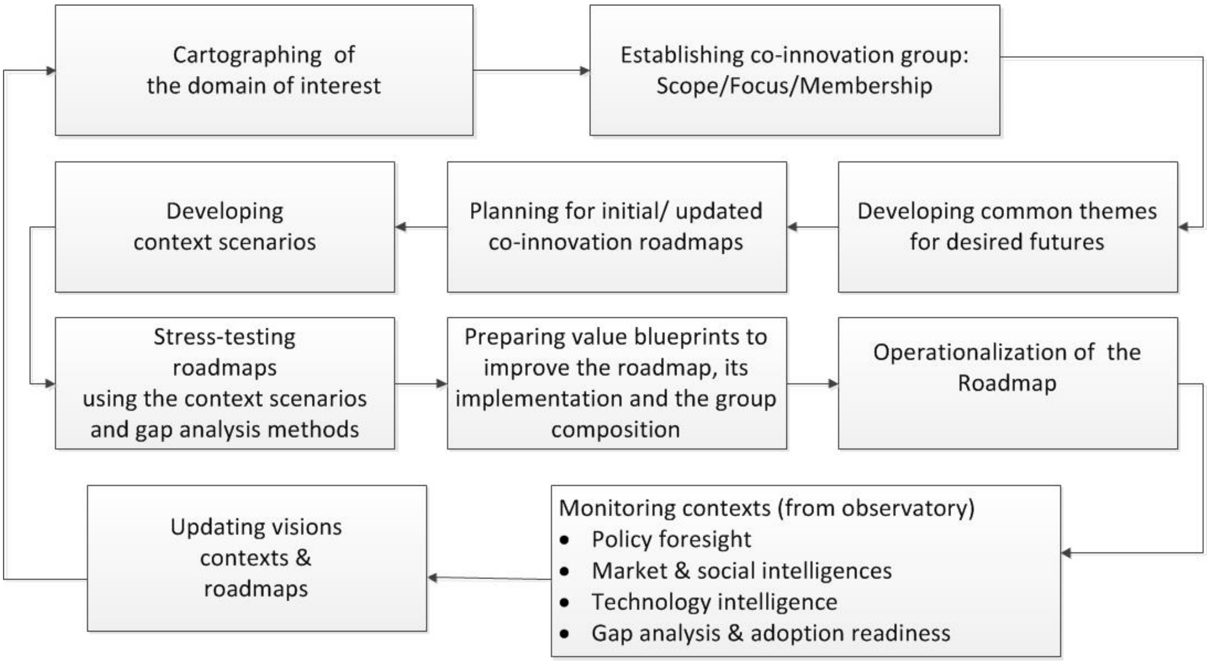


Figure 64. Main Processes for 'Dynamic Roadmapping'

As depicted in Figure 64, the main processes of the 'Dynamic Roadmapping' framework consist of 10 steps as they are depicted in:

1) The roadmapping facilitation team establish an initial observatory intelligent network which performs an initial Cartography of the domain of interest.

2) Form the co-innovation group.

   The roadmapping facilitation team uses the input from the initial domain cartography and the ARE-IN analysis (from Future Search method) in order to form the initial roadmapping co-innovation group.

   The roadmapping facilitation team supports the co-innovation group in order to:

   - Define scope, focus and membership.
   - Define Roadmap architecture.
   - Define organisational structure and administration.
   - Provide tools for the group to work together such as web portal, collaborative modelling tools, communication tools, etc. When possible, these tools are based on tools already used by the co-innovation team participants.

3) The co-innovation group articulates their desired future and plans for common themes.

4) The co-innovation group develops the initial co-innovation roadmaps of how to get from there to here.

5) The observatory intelligent network supports the co-innovation group to map out the present context. Map out assumptions about the future and create future context scenarios. (Perform foresight activities in collaboration with the observatory intelligent network).

6) The co-innovation group with the support of the observatory intelligent network stress-test their initial roadmaps to take into account of the present context and possible alternative futures, gaps in roadmaps adoption and inform the observatory.

7) The co-innovation group prepares the value blueprints (of all necessary co-innovators, adopter decision makers and users which make up the co-innovation eco-system) to improve the roadmaps and the group composition.

8) The co-innovation group starts the operationalisation of the roadmaps. This activities kick start *the dynamic phase* of implementing the roadmaps.

9) Monitoring Contexts: The observatory intelligent network provides continuous foresight, market, social and technology intelligence, and identifies gaps related to the roadmaps' implementation. Based on this monitoring and analysis, it provides to the co-innovation group reports and alerts about relevant changes taking place, which could affect its desired futures and or its roadmaps.

10) The co-innovation group informs the cartography of the domain of interest, and enhances its membership, the scenarios and initial roadmaps, and the innovation blueprints as required. It also provides feedback to the observatory intelligent network.

This is a dynamic, iterative process with feedback loops that continues until all the roadmapping actions and strategies are implemented by the co-innovation group.

Cartography of the TEL domain and ***establishment of the co-innovation group.***

The process starts with the *roadmapping facilitation team* planning the roadmapping process and the establishment of both of the *co-innovation group* and the *observatory intelligent network*.

The roadmapping facilitation team designs an observatory function and establish an initial intelligence network that will kick-start, update and maintain the cartography map of the domain. It will be also used in order to integrate different intelligence related to Policy foresight, industry state of play, research, practice and technology trends. This intelligent network is formed from PhD students, researchers, technologies, domain experts and technology experts. The initial cartography produced by the observatory network will be used to identify innovative communities who share similar and or complemented objectives, activities, in order to form the initial co-innovation group. If major conflicts are identified different co-innovation groups may emerge. In order to make sure that all necessary actors that could be needed in order to develop and implement the solutions in the roadmaps are coming together, the ARE-IN principles from Future search will also be applied.

Establishing the co-innovation group on this basis, with *clear Scope, Focus and Membership* from the start, it does not prevent later enhancement with further stakeholders based on common or complementary interests, activities and assumptions about their future visions. Continuing viability is based on consensus - when major conflicts are identified, splinter groups may be formed.

Main outputs: cartography map; initial co-innovation group, web and social networking tools, modelling tools, online observatory portal.

<u>Form the initial Co-innovation roadmaps</u>

The first task of the co-innovation group is to create their draft roadmaps.

- Members of the co-innovation group articulate their shared desired future and identify its major sub-themes, thus agreeing in a common strategic perspective.
- For each theme, the co-innovation group creates an initial roadmap on how to get from here to there. During this stage, they **plan their initial co-innovation roadmaps** with sub-goals inspired by the desired future, the things that will need to be set up, products produced, activities undertaken, all set out against time. This involves an initial gap analysis among what will be needed, and is currently available, and what is in the process of being developed, as well as who should be involved in the development process. Figure 65, depicts the processes involved for forming the initial roadmaps.

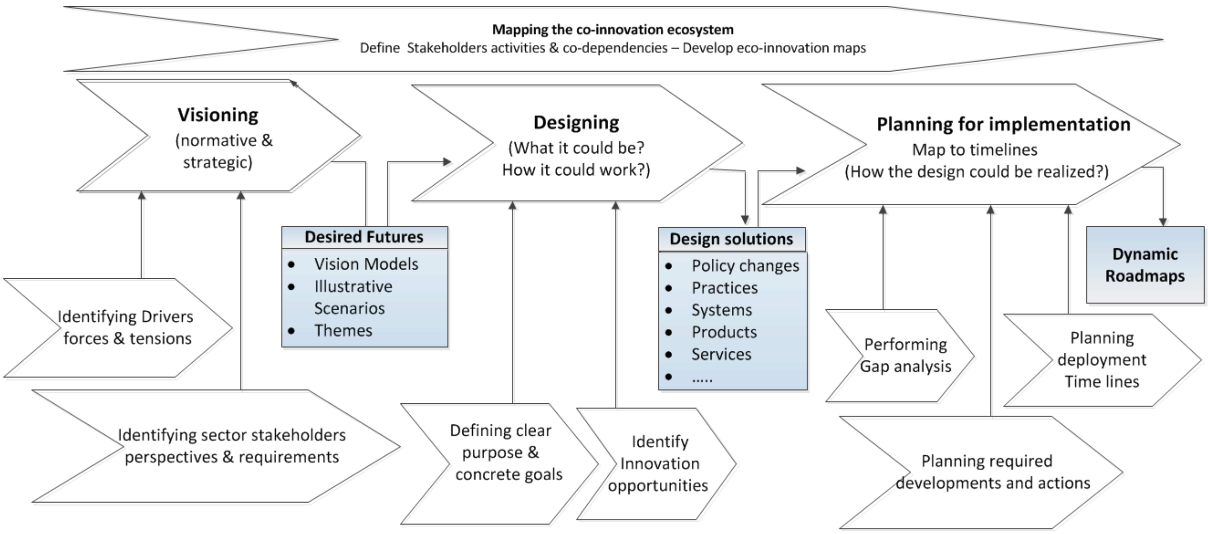


Figure 65. basic process for developing the co-innovation roadmaps

Why? - Visioning process. Activities in this process include:

- Identifying key related drivers, forces and tensions in the sector

- Identifying stakeholders perspectives and requirements
- Identifying stakeholders' individual visions
- Developing shared desired future
- Identifying stakeholders generic activities and co-dependencies
- Developing co-innovators value maps
- Identifying key drivers and uncertainties to generate future context scenarios

Main outputs: desired futures definitions, common themes, vision models with illustrative examples, future contexts, purpose and scope of the roadmap.

What? – Design Process. Activities involved:

- Identifying concrete targets and goals
- Identifying innovation opportunities & value propositions
- Identifying necessary enabling actions

Main Outputs: Development of solutions portfolio (e.g. new practices, systems, products, services, processes, models, etc.)

How? – Performing gap analysis and develop plan with timelines maps.

Activities involved:

- Identifying any required negotiations and/or lobbying
- Identifying required training programmes and resourcing
- Identifying technology development and other developments
- Plan deployment timelines
- Develop Roadmap charts

Main outputs: online roadmap charts

<u>Map out present context – development of context scenarios</u>

Using an exploratory scenario planning approach, the co-innovation group together with the observatory intelligence network map out the present context, the key uncertainties about the future and create the future context scenarios. They also identify possible signals that would provide an early indication that the world is moving towards a given scenario. (Note: Since, this part involves expert's knowledge the observatory intelligent network could initially develop the context scenarios and submit them to the co-innovation group for their validation and approval.)

They start by work out their assumptions about the future of the wider context in which they are operating, but which is largely outside their control, and the ways it may develop that is relevant to their shared desired future. These influence factors and uncertainties are used in order to understand and group tensions and develop **context scenarios** that the developed roadmaps will be played out in the future. In most cases, a 2x2 scenario matrix approach is used in order to limit the number of scenarios in 4 and make their analysis and stress-testing more manageable. In case when large amount of data already exist electronically, computer simulation approaches could also be used for developing a large number of context scenarios.

Main outputs: assumptions, trends, weak signals, tensions, initial context scenarios.

Stress-testing the roadmaps against the context scenarios

It is important to stress-test the co-innovation roadmaps at each stage in their development.

The Desired Futures are at first placed in each of the Context Scenarios, in order to identify gaps and to develop a draft alternative course of actions, but starting with a single path (operational plans) for the near, and relatively more certain, future.

Once the initial roadmaps have been developed by the co-innovation group, the co-innovation group with the help of the observatory intelligence network continue this process by stress-testing each roadmap against the context scenarios. They compare their roadmaps with the various ways in which their operating contexts may evolve and how this could affect them. Using this approach they create alternative pathways for the roadmaps that take into account the present context as their common starting point and adapt to the possible alternative futures.

One technique that can be used is based upon a four-fielder approach, of a 2x2 scenario matrix. The aim is to use these context scenarios to surface assumptions and key areas of uncertainty, to watch for signals or events that could impact the realization of the desired scenarios and their roadmaps. Delphi, and focused groups are used in order to further discuss the results of the contexts scenarios and identify signals that could influence the identified drivers, trends and tensions.

In addition a series of ‘what-if’ type of questions are used with respect to the issues outlined in the context scenarios; For example, what if the economic recession will continue for the next 5 years? What if a particular policy will lift adoption barriers (or hinder implementation process?) The what-if assumptions can be various hypotheses that influence the realization of the roadmap under each of the context scenarios. They can stem from the trends, weak signal, and tension analysis. An analysis of such hypothetical assumptions and tensions is then carried out for each roadmap under each scenario. In a sense, assumptions can be likened to positions and tensions can be likened to directions (alternatives). In combination they determine some conditions under which, plausibility indicators can be determined. This helps provides a kind of cross-impact analysis in modelling how the combinations of shifts (causes) interact with each other to create the combined shift (effect) on the roadmap under scrutiny.

It also provides a set of indicators to the observatory in order to monitor them and provide alerts to the co-innovation group when they are signals that these indicators might change.

Figure 66 demonstrates this approach of stress-testing the roadmap outputs in the light of the tensions outlining the context scenarios. Each roadmap is examined and hypothetically played out under the conditions of each context scenario: Such an analysis provide an indication about a) the effectiveness of the roadmaps according to each scenario (e.g. are the desired scenarios/goals, solutions, actions of the roadmap still relevant? are they becoming more or less important?) and b) the efficiency of its operationalisation part (e.g. the planned solutions and alignment of resources, technological solutions chosen, skills needed) is becoming easier or more difficult to achieve.

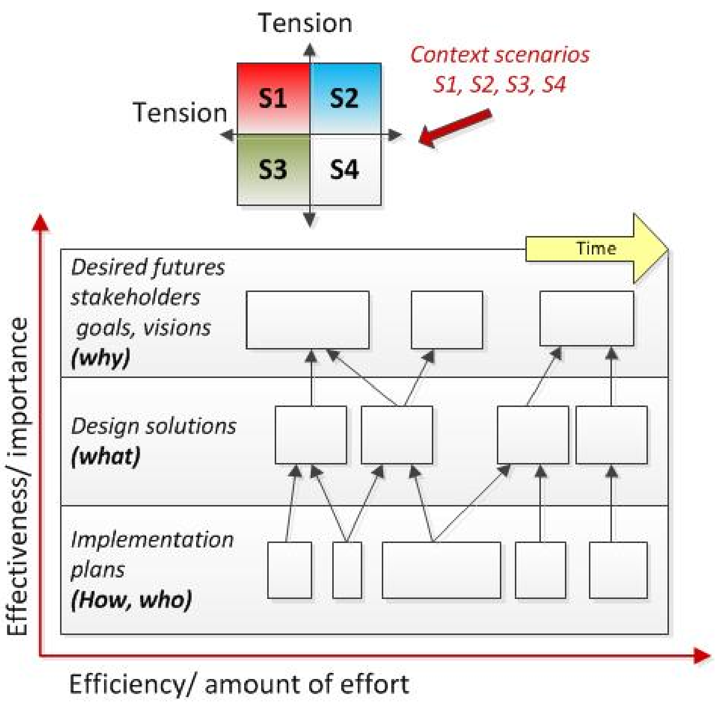


Figure 66. Roadmap stress-testing using the context scenarios and Effectiveness and Efficiency dimensions. Figure based on (Kamtsiou, Olivier, et al. 2013) *from figure 3.4, p. 52*

Performing gap analysis

In parallel, ***a gap analysis*** is performed by the Observatory intelligent network in order to identify gaps between the roadmapping plans and their implementation. Emphasis is given on the efficiency of the technical solutions and their feasibility in terms of technology readiness. Methods used are current state of the art assessment, trends projections, lifecycles and S-curves, SWOT analysis, technology adoption readiness, market adoption readiness and assessment of market relevance of the solutions. The results of this analysis are fed back to the co-innovation group in order to consider them for updating their initial roadmaps and support them in preparing their *'innovation blue prints'*.

The first step will be to identify the strengths, weaknesses, opportunities and competence-related threats to realize each roadmap. This analysis provided the observatory and the co-innovation group with the distinct competencies that we have today (Strengths) and the key capabilities (opportunities) that we need in the future in order to realize the particular roadmaps and their desired scenarios. In addition, the negative or problematic factors (weaknesses, some threats) that hinder the realization of the roadmaps are identified. The results from the context scenarios' analysis will also be used here in order to bring up the assumptions and preconditions behind the analysis.

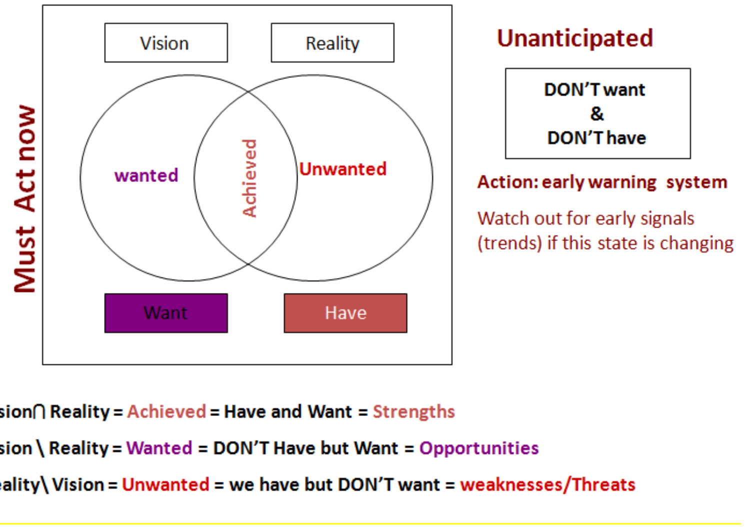


Figure 67. SWOT analysis framework. Adapted from (Kamtsiou & Naeve 2008) *from figure 3, p. 2*

As shown in Figure 67, an adapted SWOT methodology (SWO) is used. This is based upon the conventional SWOT methodology but threats are implicit within a single cell, "What we do not need". That cell covers both weaknesses and threats. The purpose of focusing on what we do not need is as mentioned above to bring out the assumptions and preconditions that have to be fulfilled for the desired scenarios to be realized. This approach aims to identify the current strengths (existing competencies), weaknesses (missing or inadequate capabilities), opportunities (key future capabilities) and capability-related threats (problematic factors such as competition for sources of capabilities and resources needed to acquire new capabilities or re-direct existing capabilities) which will contribute to the realization of the desired scenarios and the roadmaps *(Kamtsiou & Naeve 2008).*

- Vision∩Reality = Achieved = Strengths (existing capabilities we have today and want for the future)
- Vision\ Reality = Wanted = Opportunities (key future capabilities that we are missing today but we want for the future)

- Reality\ Vision = Unwanted = Weaknesses (Problematic factors such as competition f or sources of capabilities and resources needed to acquire new capabilities or re-direct existing capabilities)

DON’T want &DON’T have = Unanticipated today (watch out for early warnings if this part is changing

Main outputs: alternative implementation paths, state of the art analysis, gaps, strengths, opportunities, threats, weaknesses.

Preparing the roadmapping value prints

Part of the stress-testing activity is the preparation of **value blueprints (**who else needs to either co-innovate or be able to adopt parts of the innovations planned in the roadmap in order for the value propositions of these innovations to reach the final users). All the necessary co-innovators, adopter decision makers and users, which make up the functional value propositions of the co-innovation roadmaps are listed, analysed and aligned. Based on this analysis, the supporting observatory together with the co-innovation group prepare the roadmap’s adoption innovation blueprints in order to cross-check the group’s composition, ensure the roadmap’s implementation, and manage the necessary changes in the co-evolution of all innovators and adopters. The Adner’s (Adner 2012) methodology from his book wide lenses is used for preparing the value blueprints.

The results from the above activities are shared with the ***observatory***, in the form of key areas to watch, indicators, the initial roadmap and the value blueprints. The observatory monitors the contexts and responds with commentary and horizon scanning to inform the co-innovation group in its next steps. In addition, it continues to provide strategic analysis of weak and strong signals, future trends and an analysis of research challenges in the area (as part of the Policy and Research roadmapping activities). The co-innovation group’s desired future and goals, the sub-themes, the key drivers and critical uncertainties with their associated context scenarios, the roadmaps and their possible future branches, are used as relevance filters for horizon scanning and weak signal identification.

Main outputs: alternative directions, indicators of change, value blueprints, updated cartography, and enchased co-innovation group membership.

Start the dynamic phase of implementing the roadmap

During this phase, the development of the first draft Roadmap by the co-innovation group moves towards implementation. Then, the dynamic part of its assessment against emerging reality is done during the monitoring phase.

At this stage, PESTLE drivers, weak Signals collection and analysis focus on early indications that the assumptions and indicators described in the context scenarios are actually changing. As time passes, we witness that specific driving forces (weak signals today) play out an important role in visions of the roadmaps developed by the co-innovation groups. Then it becomes clear that some of the possible context scenarios and their associated strategies need to be updated and further developed to reflect this emerging reality. Additional gap analysis and adoption analysis are performed by the observatory and inform the co-innovation group. The co-innovation group update its roadmaps accordingly.

Figure 68 shows the Observatory's key activities (arrow boxes) and key outputs (rectangles) which are involved in developing the initial roadmaps of the co-innovation group and stress-testing them against the emerging reality.

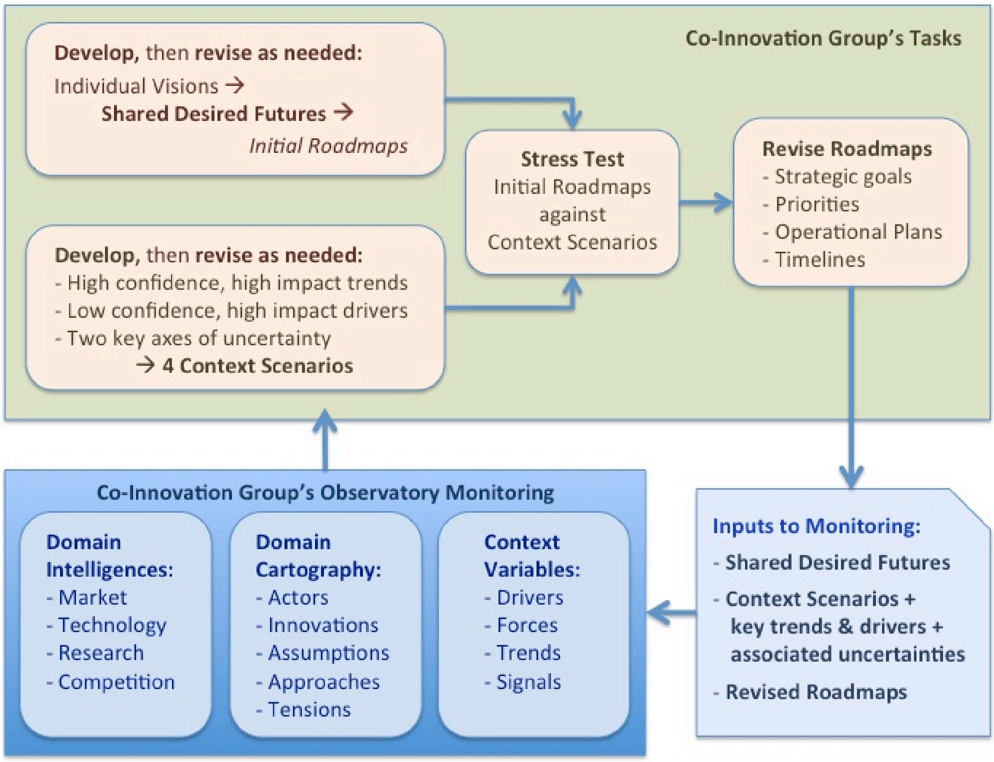


Figure 68. Testing roadmaps against the emerging reality: the Observatory function

Main activities include:

- Receive alerts from the observatory about relevant changes taking place.
- Update and adapt the roadmap, context scenarios, goals, the desired future and/or the co-innovation blueprints as judged to be necessary.
- Update the cartography of the domain of interest.

At this point, the group enters the 'Dynamic Roadmapping' stage:

- Each participant in the co-innovation group begins planning their own activities in the light of the roadmap and sharing these with the others and the observatory, as well as subsequent progress reports against these plans.
- All participants also join with the *observatory* in horizon-scanning activities.
- As necessary, the observatory alerts the innovation cluster to significant signals they have picked up, to relevant unexpected developments, and to trends that appear to be changing their trajectories. Services such as PESTLE analysis, policy foresight studies

such as DELPHI and weak-signals analysis, gap analysis, crowd sourcing, focus groups, are also provided to the groups as part of the observatory services etc.

- The group then has to review their plans, *updating visions, contexts and roadmap,* or, in the extreme case, abandoning their whole project. This updating is done in terms of two important dimensions of relevance and efficiency: a) are our purpose, goals and visions still relevant in relation to the emerging contexts? Are our processes, technologies, operational plans still efficient for achieving our goals and visions?

Implementing roadmaps in slow-moving contexts, such as education for example, demands that this process is repeated, but building on previous iterations and maintaining the knowledge discovered in the observatory and sustaining the co-innovation group, rather than starting afresh. This sets out the basic outline for the dynamic, meso-level, adaptive roadmapping. There are many possible ways in which these steps could be carried out. For example, system thinking approaches can be used instead of context scenarios; cross-impact and Bayesian approaches can be used instead or in combination of Delphi studies in order to identify and interpret weak signals and trends; different bibliometric approaches together with classification techniques can be used for capturing and classifying new technology developments. The steps outlined above are a good way of increasing the chances of success in adopting dynamic roadmaps. This is because in a complex systemic innovation system, there is a need to involve more than just the innovator and their customer. The whole process to mainstream the innovation will take years rather than months and the operating context is likely to undergo significant change over that timeframe.

Main outputs: continuously updated roadmaps, updated context scenarios, updated desired scenarios, updated cartography, enhanced observatory and enhanced co-innovation group.

3.4 Process framework implementation via five key workshops

The co-innovation group achieves the development, stress-testing and updating of their roadmaps through five (5) types of workshops and (in-between) several other online meetings and virtual collaborations. Figure 69 shows the five facilitated face-to-face workshops and the key steps involved in order to create the roadmaps and be ready to monitor them in the live phase. It also depicts the virtual collaborations and the observatory activities performed in parallel.

Once formed, the co-Innovation Group will need to work together ***(workshop 1: shared perspectives)*** in order to create their shared desired futures in the form of desired scenarios, and to develop and implement their roadmaps. This is a key step in uniting the group in a common purpose. Given this approach it should be noted that the initial desired plans do not need to be worked out in great detail from the very beginning of the process, since they will be continuously updated across the entire timespan of the roadmaps development and implementation. In a turbulent environment, detailed longer-term planning may then be prove no longer applicable when the time comes. Consequently only short term planning is worked out in any detail, sufficient for co-innovators to start working together, while medium and longer term planning get worked on as they get nearer and can be easily adapted as needed.

The initial visions developed are modelled, compared, grouped and further articulated via a series of online consultation meetings.

In parallel, the co-innovation group in collaboration with the observatory intelligent network will also identify and deal with their critical assumptions and uncertainties about the future as it may impact on the implementation of their shared desired future and roadmaps ***(workshop 2: Context scenarios)***. This is done during workshops and followed up online meetings. The aim is the generation of future context scenarios, using common scenario planning approaches. This typically results in mapping out four possible and equally plausible possible futures for the wider context in which they are operating, but over which they have little or no control.

A workshop with the industry ***(workshop 3: industry perspectives)*** is then scheduled in order to evaluate the market relevance of the visions and identify technology and market gaps. This step is necessary, especially in the case that it is very difficult to include and engage industry participants from the very beginning of the co-innovation formation process. During the workshop industry participants are invited to join the co-innovation group, and map their interests according to the co-innovation visions. The results of this workshop are made available through reports and models to the enhanced co-innovation group and are discussed during online consultation meetings.

The co-innovation group then develops their initial roadmaps ***(workshop 4: initial roadmaps)*** by identifying the sub-goals that they will need to achieve, tasks, technologies and resources that will then be needed to realize the goals, and setting these out over a short, medium and long-term timeline. Inputs from the observatory activities such as 'Gap analyses, 'market relevance' and 'technology assessment' are also used in order to validate and update the initial roadmaps. A series of online consultation are scheduled in order assess the input from the observatory and to finalise the initial roadmaps.

The co-innovation group **(*during workshop 5: Stress-testing initial roadmaps*)** uses the support of the observatory intelligent network in order to 'stress-test' their first cut roadmaps, by placing them against the context scenarios and in turn exploring whether they need to be adapted or changed in the light of the eventualities described in the scenarios are being realized. This may then result in future potential branching points in their roadmaps, thus completing the second initial planning stage. At the same time, the co-innovation group develops the co-innovation blueprints in order to support the roadmaps development and adoption. 'What if' analysis is also used in order to explore the different issues brought out from the context scenarios.

In the third dynamic or adaptive stage of the 'Dynamic Roadmapping' process, when implementation is underway, the roadmaps, the context scenarios and the desired future itself are all open to change in the light of changing circumstances. The Desired Future, Context Scenarios and challenges are fed into an open collaborative observatory, which looks out for events, changing trends and weak signals, feeding them back as alerts to the co-innovation group. The co-innovation group then has to decide whether to amend its roadmap, revise its context scenarios, or adjust its desired future. Beyond the next increment, all is provisional.

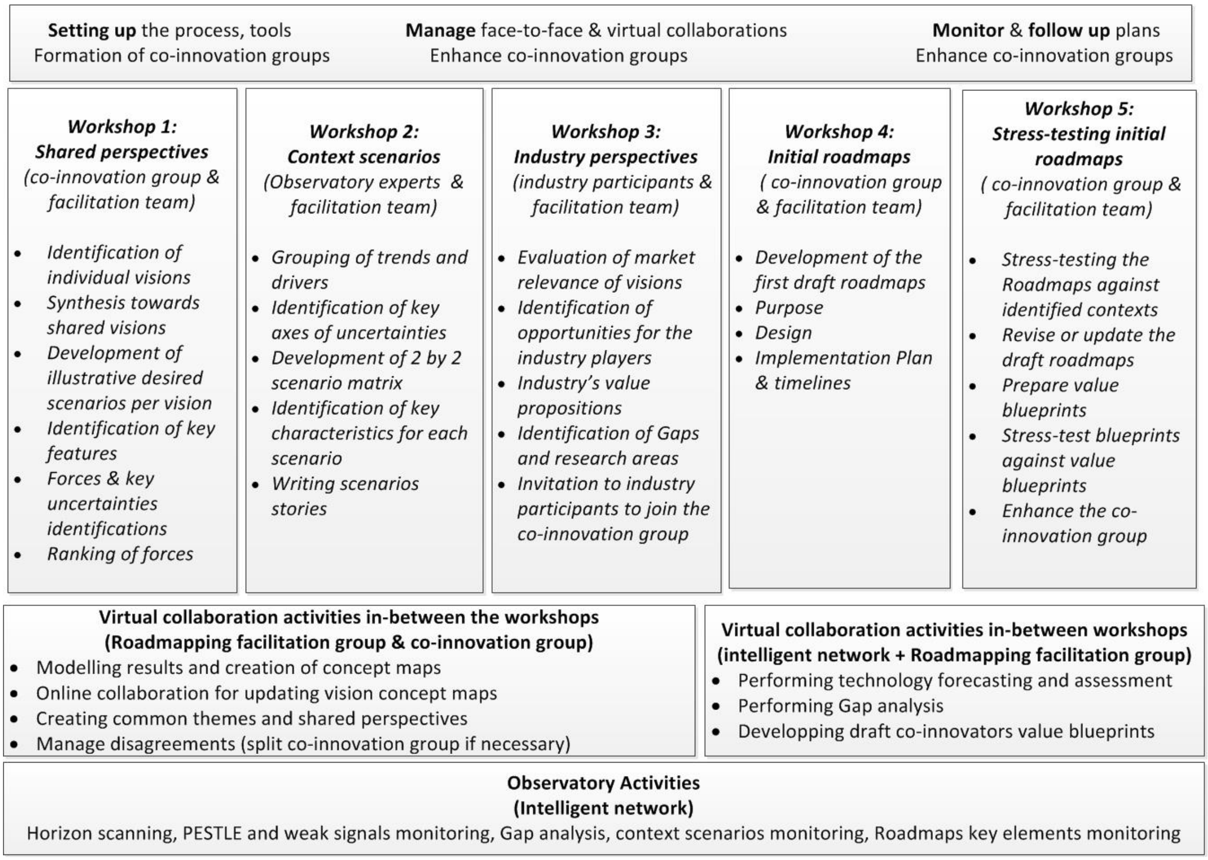


Figure 69. Implementation via five key workshops and online consultations

Figure 70 is another view of the main activities. It shows a high level representation of the five workshops activities grouped according the 'Dynamic Roadmapping' process. The first two sets are related to the foresight (normative and exploratory activities), i.e. a) desired future paths and b) Contexts planning paths, which are running in parallel. The third set, c) Roadmapping adoption paths relates to the roadmapping operational and adoption activities. This third set of activities refers to the dynamic part of the roadmap, during which, the roadmaps are developed, implemented, monitored and updated.

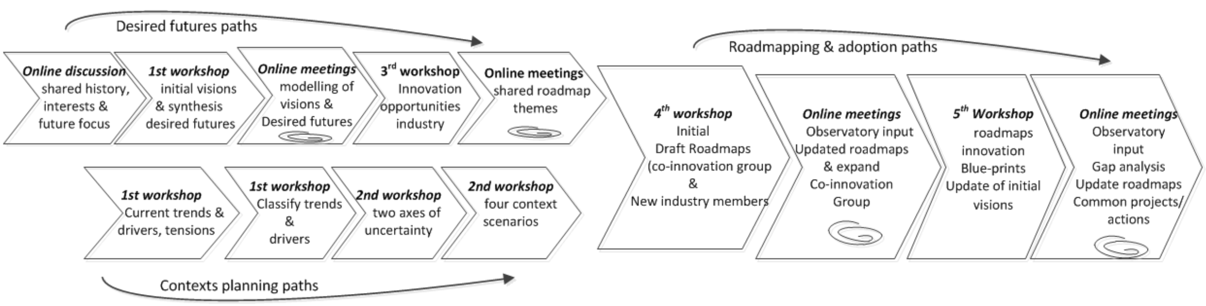


Figure 70. Workshops activities grouped according to Desired Futures, Context Planning, Roadmapping and Adoption Perspectives.

Chapter 4: Methodology and Research Design

The research methodologies in this thesis were chosen in accordance to the nature of the research problem and the aim and objectives set out for this research.

The nature of the research problem is defined in terms of recognising roadmapping as both, a participatory learning process and as a dynamic process which is systemically interlinked to wider historical, technical, political and social contexts. Therefore, the interpretive paradigm is adopted, which considers reality and as social construction ("emergent, subjectively created and objectified through human interaction") (Chua 1986) The objective of this research is the co-creation and sharing of knowledge within a roadmapping community that develops Meso-Level Roadmaps and among the community and the researcher, who developed the framework for meso-level Dynamic roadmapping.

The current thesis utilised Field Study, Literature Review, Action Research, Case Study and Conceptual modelling as main research methods.

Case Study and Action Research are both considered appropriate interpretive research methods. Case Study is used for exploring complex social phenomena and processes which require in-depth descriptions (Yin, 2009), while Action Research is used for the ongoing development of a community of diverse range of stakeholders, who are actively set challenges, develop, implement and manage their strategic planning (Schaff & Greenwood 2003). Moreover, Case Study is usually the method used for presenting and analysing the results produced from Action Research (Greenwood & Levin 2007).

In addition, a Field study (chapter 5) was employed as an "empirical study" in order to demonstrate and map the evolution of roadmapping in EU-TEL projects, across TEL domains (e.g. schools, universities, professional settings and lifelong learning) and to address the research questions stated for this thesis (chapter 1, section: 1.5). It served as secondary data for identify gaps in practice and for developing the Meso-Level Dynamic Roadmapping model. In this way, the model was informed directly from knowledge that the researcher gained by means of empirical observation and practical experience. This empirical study was complimented by an extensive literature review and analysis in roadmapping, foresight and innovation management fields presented in chapter 2, in order to further explore the gaps in roadmapping theory and practice, demonstrate the need for 'Meso-Level' roadmapping and formulate the research questions in this thesis. The Literature review conducted in this thesis was not limited to a specific domain, as in the case of the field study, but it focused instead in the systematic analysis of the different theories and practices related to roadmapping, foresight and innovation management approaches. Additionally, in order to address in full all research questions and gaps derived from literature review and from practice, a Case Study methodology was employed. Moreover, both the Action Research and the Case Study helped to contextualise the 'Dynamic Roadmapping' model and assess its usefulness within an actual community of practice in real contexts in the schools sector. Conceptual modeling was used in order to code, map and abstract the results from the Field study, literature review and Action Research and develop the new concepts, models and process frameworks of Dynamic Roadmapping. This approach is in line with the experiential learning model (Kolb 1984), where the researcher begins with experience gained from their practice; makes observations and reflections; forms new concepts and models; Tests these models in real life new context; generates new knowledge.

4.1 Action Research

Action research is defined by Greenwood, Morten (Greenwood & Levin 2007), in their book “Introduction to Action Research” as a “social set research carried out by a team that encompasses a professional action researcher and the members of an organization, community or network (“stakeholders”) who are seeking to improve the participants’ situation” (Greenwood & Levin 2007). The social research is conducting using collaborative methods which satisfy both rigorous scientific requirements and support democratic social change (Greenwood & Levin 2007).

Action Research methodology is employed in this thesis in order to apply and evaluate the Dynamic Roadmapping framework in real life contexts within a real community of stakeholders. Two of the main aspects of the Dynamic Roadmapping model are the ‘Meso-Level’ concept and the intended application of the model for developing and managing ‘Systemic Innovations’. In terms of the ‘Meso-level’, the Dynamic roadmapping model is used as a process framework by stakeholders in order to develop, manage and implement their own roadmaps by themselves, for themselves, instead of the dominant expert-based roadmapping approaches, where experts are developing roadmaps for others. Action Research is chosen as an appropriate participatory research methodology for the development of this work, because it utilizes collaborative processes and action design, which are both core elements for any roadmap development. It also engages the roadmapping community and the researcher in a mutual learning process, a core element of the ‘Dynamic Roadmapping’ approach (Greenwood & Levin 2007). At the same time, Action Research is an appropriate methodology for dealing with systemic innovations. These are complex innovations that are interrelated to and affected by PESTLE phenomena that are evolving in the innovations’ contextual environments. Under this view the roadmap is considered as a system, which is interconnected and co-exists in relation to its environment. As the roadmap starts to get implemented, the stakeholders’ views and intensions (visions, actions) are also evolving and they are affected by emergent phenomena in their environments; therefore, the visions in the roadmaps are also dynamic and evolving and the roadmap itself needs to be dynamically evolved and updated. Dynamic Roadmapping provides an approach to understand and analyse the interrelationships, among the visions and actions of the actors in the system and the interrelationships among the actors and their environment. This systemic view of roadmapping necessitates the participation of all stakeholders who are needed in order to articulate their visions, value propositions and strategic plans and take actions to build the system. Action Research is a suitable research methodology for system thinking approaches. In that respect, “Action Research carried out with a systemic perspective in mind promises to construct meaning that resonates strongly with our experiences within a profoundly systemic world (Flood 2010)” .

In general, Action Research methodologies emphasise both action and research. Action is taken in order to initiate and make change in a community or a program. Research relates to the increased understanding of the researcher and/or the community of the methods and processes used in order to bring about these changes and often it contributes to the general knowledge of some wider community. It takes into consideration the participants viewpoints and intentions and emphasises a democratic process. It is a process that promotes transformative learning for both the researcher and the community (Greenwood & Levin 2007). The aim is to emancipate the community to bring about important social and organisational changes. In Action Research, knowledge, theory and practice are informing each other in an ongoing process (O'Brien 2001), (Bolan 1980), (Schon, 1983). Similarly, in this thesis, the 'Dynamic Roadmapping' model has been initially informed from the existing roadmapping theory (literature review), as well as the previous empirical practice knowledge of the researcher, and later on, from the actual practice of the roadmapping community who implemented the model in the school sector. The results from the action research are belonging mutually to the community and the researcher. The results from the Action research are analysed and discussed in the format of a case study.

As mentioned above, Action Research methods demands for real factual settings, with real communities facing real problems in a local practice and who want to take social oriented action. They also demand for collaboration between the researcher and the practitioners of the local practice (Goldkuhl 2011).

The Action Research elements of this thesis are:

- *Community of local practice:* Stakeholders and Practitioners, who are actively involved in the Schools education sector and in activities that aim at changing/transforming the current practices. These participants are forming a community called 'Co-innovation group'. They introduce the challenges and questions related to the current practices, identify visions, develop action designs and implement actions. They produce the empirical input for implementing and validating the 'Dynamic Roadmapping' model and process framework.
- *Action researcher:* Author of this thesis. Her role is to identify research issues, select the research methods, design the research planning, model the results and theorizing. The researcher has performed joint analysis with the practitioners in their attempts to make sense of the efficiency of methods used and results. This involved coding and abstraction (modeling) of information and results. The researcher created further abstractions (new concepts, models and frameworks) that go beyond the specific case study of the local practice. The local practice was explored and analysed by the researcher via a case study format. The result was the 'Dynamic Roadmapping' model and process framework.
- *Social oriented action from the perspective of local practice:* 'changing schools to creative learning environments'.
- *Research question from the perspective of the researcher:* How to develop Meso-Level Dynamic Roadmaps for managing systemic innovations and extend the theory and practice in Roadmapping.

- *Contribution to theory:* extension of current innovation management models and roadmapping methodologies.
- *Contribution of local community practice:* Dynamic Roadmaps for managing innovation at schools.

"Susman & Evered (1978) have identified five main stages in Action Research: 1) diagnosis, 2) action planning 3) action taken, 4) evaluate work, 5) specify learning. 'Diagnosis' relates to identification of main challenges and the reasons for chance; action taken relates to the design process that will lead to desired change; 'action taking' relates to the implementation of the plans; 'evaluate work' relates to the evaluation of the theoretical effects of the action; and 'specify learning' relates to lessons learned through the process (Susman & Evered 1978).

In this thesis the 5 stages are classified as below:

- **Diagnosis:** During this stage, information about the domain is mapped as an ongoing dynamic cartography, which identifies and maps out the domain's issues, main challenges and controversies, including key stakeholders and other important actors associated with these challenges. Foresight scenarios are also developed in order to assess the main trends and other phenomena in the wider contextual environment that could compel changes in local practice. An observatory function is established to inform the community of practice.

- **Action planning:** During this stage, the community of the schools stakeholders ('co-innovation' roadmapping group) are working both face to face and online using web-based Roadmapping tools. They develop and describe their strategic visions, develop their roadmaps and test them against the information gathered in the Diagnosis stage. The model of Dynamic Roadmapping and the process framework guides the planning process.

- **Action taken:** This corresponds to the dynamic phase of Roadmapping, where the co-innovation group is starting to implement their roadmaps and continuously monitor them based on alerts, signals and events provided by the observatory function.

- **Evaluate work:** the empirical and theoretical work is synthesised, analysed and evaluated by the researcher via a case study. The participants are evaluating their work, integrate it in their own plans and strategies and they make suggestions to the European Commission for further improvements.

- **Specify learning:** Based on the case study analysis, conclusions are drawn and further research is suggested by the researcher.

Table 9 shows the inputs and outputs related to the Action Research process from the perspectives of both the Community of local practice (co-innovation group) and the researcher (theorizing perspective).

From	Inputs	Outputs	Methods & tools used
Community of Local practice ***(Roadmapping co-innovation group)*** **Note**: the co-innovation group is assisted by and it is part of an ***Observatory network of experts***	- Challenges and needs based on real problems - Assumptions - Cartography of actors, practices, research, issues and controversies - Foresight analysis - Signals collection and analysis - Socialisation, dialoguing, collecting, analysing, synthesizing and presenting data	- Local practice contributions to practical concerns of the roadmapping communities in the schools sector (cartography, visions, roadmaps, scenarios, collaboration blueprints, implementations, testing, changing practices)	- Foresight - Roadmapping - Stress testing - Conceptual Modelling - Domain Cartography - Social networking analysis tools - Web/Collaboration tools - Workshops - Surveys - Interviews - Web Observatory
Theorizing (Researcher)	- Formulation of research questions, - Selection of theories, models, methods (e.g., Theories: SECI, Activity theory, systems thinking, change management) and Methods (e.g. methods: foresight, roadmapping, Search Conference, domain cartography, change management models: co-innovation blueprints, conceptual modelling, workshops, questionnaires, surveys, case study, social networking analysis) - Community development: development of organisational eco systems of stakeholders: co-innovation roadmapping community - Facilitating, collecting, analysing, modelling, reflecting, synthesizing, updating	- Contributions to theory and practice of roadmapping, new concepts (e.g. Meso Level Dynamic roadmapping, co-innovation roadmapping groups, domain cartography), conceptual models and process frameworks. - Demonstration of Practical Implementation through Roadmapping case study	- Action research - Field study - Case study - Conceptual Modelling - Organisation and management of workshops - Organisation of surveys and interviews - Organisation and planning of Observatory function - Conceptual modelling tools - Web collaboration tools - Web Portal

Table 9: Inputs and outputs in the Action Research process

4.1.1 Future Search and Search Conference (FSC)

There are several research techniques that can be utilised by Action Research in order to facilitate change via community strategic planning and action, and to produce data for theorizing and knowledge creation (Greenwood & Levin 2007). As mentioned above, Action Research uses collaborative processes among stakeholders in a local community in order to produce an action design and implement it. Dialoguing based methods, such as learning cafes, workshops, and interviews are usually employed. The Future Search (Weisbord & Janoff 2000) and its Search Conference (Emery & Purser 1996) are methods developed specifically to suit the requirements of Action Research (Schaff & Greenwood 2003), (Flood 2010) because they address real problems, in real social settings and involve all necessary stakeholders in developing knowledge and plans on how to deal with those problems. They have been chosen as an approach to Action Research in this thesis, since they also reflect 'systemic thinking' (Flood 2010), which is a cornerstone in 'Dynamic Roadmapping' model.

Future Search (Weisbord & Janoff 2010) method and its Search Conference are (Emery & Purser 1996) intensive workshop based management approaches aiming to help social systems to become adaptive. Future Search provides the framework of the approach, while Search Conference is the actual tool in a form of a workshop that implements the method. They have been derived from the work of Fred Emery and Eric Trist and have been successfully applied over several decades worldwide on a hundred of occasions. These methods are used in order to establish common ground across all the key stakeholders, who need to be brought to work together in order to solve a problem in the system.

The Search Conference requires that all key stakeholders meet face to face, establish trust, and recognize their differences. Where there is agreement on a goal, they can formulate a shared future that addresses all their needs and concerns and set out the basis for an action plan that they can then take forward collectively. This is a complex undertaking and takes time. The Future Search format requires all stakeholders to commit to work together for three to five consecutive days in order to achieve this goal. This is because of the belief that no amount of separate bi-lateral meetings can achieve comparable outcomes of trust, shared vision, commitment, and follow through. The format also is ideally framed around 64 participants in 8 stakeholder groups, but typically there are between 60 and 70 participants. The main effort in such a meeting lies in the meticulous preparation required to prepare it. A large part of this lies in obtaining the commitment of all key stakeholders to participate, making sure they fully understand what it is addressed and what outcome is being sought. The Search Conference has three phases (Emery & Purser 1996):

Phase one (environmental appreciation)
- Changes in the world around us
- Desirable and probable futures

Phase two (system analysis)
- History of the system
- Analysis of present system
- Desirable future for the system

Phase three (Integration of system and environment)
- Dealing with constrains
- Strategies and action plans

The success of the FSC depends on ensuring that all key players and decision makers are personally involved. Participation of stakeholders is of paramount importance in both systems thinking and action research. All stakeholders, including all people involved in taking action as well as people affected by those actions are included in the Future Search events. The criteria used for forming a group is that between them they should have the Authority, Resources, Expertise, Information and Need ("ARE IN") that after articulating an inspiring, but feasible shared desired future, they will then be able to successfully implement it.

In 'Dynamic Roadmapping' framework a modified version of the FSC was adopted in order to:

a) Identify a commonly agreed future and visions among the roadmapping co-innovation stakeholders, and the endogenous and exogenous factors that might affect those visions. It guided the organisation of workshop 1 "shared perspectives".

b) Use a system thinking based approach in order to set the boundaries of the roadmap (the system) and its environment (i.e., identify interrelationships between the system and the environment and produce future scenarios that might affect the evolution of both the environment and the roadmap) and guide the organisation of the workshop 2 “Context scenarios”.

c) Apply the ARE-IN criteria as a top-down approach in identifying the stakeholders who are needed to build the roadmap. Similarly to FSC, in meso level ‘Dynamic Roadmapping’, it is important to bring together all necessary stakeholders in order to design, agree and implement their roadmaps see section 6.2 in case study.

d) Build trust and commitment among the stakeholders in order to take joint action .

4.1.2 Challenges

Main challenges associated to Action Research and FSC, when applied in this PhD thesis included: a) the extended time and scope of the roadmapping activities; b) the need to ensure that community representation included more than the usual suspects (core-representative groups); c) the need to deal with community power structures and disagreements; d) logistical problems related to getting people off work for 3-4 days; e) organisational problems in extending the core membership and involving the new members in the process; f) the need to deal with follow up related problems after the events, where the community members were still required to work together in order to follow up on the decisions and plans made.

The above challenges and the solutions taken are briefly discussed below and analysed in detail in section 7.4 in Chapter 7: Discussions of findings.

FSC has generally been used to resolve **one particular “stuck issue”**, which those involved, once agreed on their desired future, can then move forward and solve the problem in the short term (Ramírez et al. 2010). ‘Dynamic Roadmapping’ is targeting systemic innovations in complex domains (e.g. education), which usually take more time in order to materialise and which are characterised by several interlinked issues and greater uncertainties related to the participants’ operating (transactional) environments as well as to wider macro socio-economic, environmental and political (contextual) environments. These issues necessitate the creation of at least midterm and often long term future plans. In addition, due to the greater uncertainty, the longer planning horizons, and the systemic nature of the targeted innovations, we cannot assume that **one future**, or one straight line scenario will be materialised, but several plausible futures can emerge. Therefore, the *context scenarios based approach* in future search was enhanced by an *‘observatory function’* in order to assist the co-innovation participants to pay attention to changes in the operating and contextual environments, which could affect the desired future and the roadmaps’ implementation, in medium and long terms. In addition, the observatory function provided several intelligence streams in terms of research, policy and industry issues (see figures 68, 121, 126, 169 & sections 6.3, 6.4, 7.2.2, 7.3). This addition extended the community of stakeholders with a network of experts who had an advisory role to the community (see section 4.2.5). The researcher in this thesis was headed the network of experts and also was responsible for developing feedback loops between the experts and the stakeholders. Detailed description of the observatory is provided in sections 6.3, 6.4, 7.2.2, 7.3.

Future Search is a **consensus building approach**, which advocates that all stakeholders will agree on the desired future (Weisbord & Janoff 2010), (Ramírez et al. 2010). Therefore, the focus is on common ground, while disagreements or conflicts are set aside and they are not addressed. To address this problem, the 'Dynamic Roadmapping' approach complimented the Future Search top-down approach of forming the stakeholders group, with bottom –up methodologies, which enable innovative communities with strong complementary interests to come together and form and/or enhance the stakeholders group. A bottom-up approach was used complimentary to the ARE-IN top-down approach in order to map the domain issues and related actors and make sure that a) likeminded groups were brought together in order to minimise the management of disagreements problem b) power structures were even up by including stakeholders with less strong voices in the co-innovation group. A weak signals collection and analysis function was also employed via the observatory in order to make sure that issues "beneath the radar screens" of the co-innovation group are captured and assessed.

Another issue was **the duration** of the Search Conference. During turbulent times, it becomes more and more difficult to get the right participants, including those who have authority to act, into one room for more than a day, let alone a whole week or three days. To overcome these issues, *a hybrid approach* was taken that used adapted Future Search methodologies in both virtual and face to face environments. Web collaboration tools were employed in order to assist the participants' online communications.

Furthermore, **extending the core group** and ensuring the smooth integration of new members was difficult, especially because of the geographically-dispersed nature of the community. To solve this problem a protocol for membership issues was establish (see later section 4.2.4 in the case study). In addition, people had the opportunity to use online collaboration spaces (shared google documents, and a web portal) in order to subscribe to the aspects of roadmapping activities that best suited their abilities and skills and to contact the responsible facilitator for getting familiar with the work done so far and ways to contribute further.

Finally, although Future search is a very good approach for community development and for identifying all the necessary human, economic and physical resources, it is weak in implementing the foreseen plans and designs. To solve this problem, the Search Conference event was complimented with roadmapping events workshops 3 "Industry perspectives", and 4 "Initial roadmaps, which aimed at developing value propositions and strategic plans for implementation". Moreover, because the goals in Dynamic Roadmapping model are developed and revised over the course of the roadmap implementation subjected also to changes in the roadmap's wider environments, the related solutions are often moving targets. In order to stress-test the roadmaps against this emerging reality and understand the interrelatedness among the actors involved in the roadmap, a change management workshop was organised as workshop 5 "Stress –testing initial roadmaps".

4.2 Case Study

The results of this research are synthesized in this thesis in the format of a Case Study in order to analyse the challenges and the main findings of the Action Research exercise. A Case Study is defined by (Yin 2009) p.13 as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident." According to Yin, a case study, as a research strategy, deals with several technical situations, contemporary events, and a variety of multi-sourced evidence such as artefacts, documents and observations and it is more than a data collection method or a survey. Moreover, a case study cannot be deliberately separated from its context as in the case of laboratory controlled experiments. It also provides a holistic approach to investigate real-life events, and the related organisational and managerial processes. It has an exploratory nature targeting 'how' and 'why' types of questions. This fits very well, with the nature of foresight and roadmapping methodologies, which are exploratory in nature with foresight exploring an area (context) 'why' and roadmapping providing the innovation design 'what', 'how', 'who'. In addition, as mentioned in the beginning of section 4, case study is considered to be the standard method to synthesise the results produce during an Action Research.

A ***longitudinal*** Case Study was used due to the long term process needed to successfully develop a roadmapping community (co-innovation group), and bring together the right mix of stakeholders, who would agree to develop their own roadmaps for themselves. The actual process of roadmaps development with focus on implementation was also a lengthy endeavour, required several workshops, online meetings, and synchronous and asynchronous interactions among the members of the co-innovation group. At the same time, an observatory function had to be developed in order to support the roadmapping community in validating, testing and updating their roadmaps. This whole process, from developing the community, setting up the observatory and developing the roadmaps lasted two and a half years. This was an extended period that provided the researcher with the opportunity to observe and analyse the utilisation of the roadmapping framework in great detail. TEL was used as an application domain, appropriate for applying the Dynamic Roadmapping Framework. The chosen domain had to fulfil the characteristics of systemic innovation, and the need for a Meso-Level roadmapping approach.

4.2.1 TEL (Technology Enhanced Learning) schools' sector case study

In order to evaluate the 'Dynamic Roadmapping' model and establish its validity, the model and its process framework were applied and validated in the field of Technology Enhanced Learning (TEL), which was implemented in TEL-Map European project. It has evolved in the field of TEL, in schools and higher education sectors. The specific case study presented in this thesis was related to the schools sector with special focus *on the creative classroom societal challenge: 'changing schools to creative learning environments'.* A *co-innovation group* of more than 134 European stakeholders was formed, with the main purpose of driving towards a better TEL future, via a broadly coordinated innovation focused on school as the hub of a creative learning environment. In this approach, a co-innovation group works at a *meso level (multi-organisational)*, bringing together an *eco-system* of interdependent stakeholders with the goal of generating a roadmap based on their shared desired futures and their goals and activities. The co-innovation group is driven from the point of view of implementation, in order to bring the *'whole system'* together in a *'working innovation value network'* referred as the *co-innovation group*. This includes a critical mass of participants in order to tackle, resolve and plan solutions for TEL, which would not be possible to be achieved by individual actors working alone.

TEL as a complex systemic environment

TEL and schools domain in particular, were chosen as a case study in order to validate the 'Dynamic Roadmapping' model since, they meet the systemic innovation criteria. These innovations are driven by societal and economic changes and have high priority in European policy agendas. TEL is also characterised by rapid technological developments and growing demand for knowledge. Information and knowledge are becoming fast outdated, while the need for multidisciplinary competences from different fields e.g. cognitive, pedagogical, education management, ICT, HR, is increasing rapidly. Moreover, the systemic complexity of such innovations and their very limited scale up in European schools, make it impossible by any single company to be able to develop and implement them. Thus, *a co-innovators value network* will be required for their successful implementation and scale-up.

The evolution of the concept of ICT for learning in the European policy discourse mainly brought forward by the European Commission (EC). HoTEL project[12] indicates that policy funding reveals how the narrative has moved from a strongly technology-driven experimental-like niche at the time of the DELTA and ESPRIT programmes in the late 90s, to a more mature phase, where the main aim was to develop new solutions able to reach as much actors as possible. During the period 2002-2010, through an eLearning Action Plan – to the present phase, the key policy objective is scalability. This clearly responds to a mismatch between the recognised potential of ICT to support innovation and change in education and the reality in most European countries. Education is in fact far from having fully embedded the potential of new technologies, to improve the efficiency, accessibility and equity of training and learning systems. About 63% of nine year olds do not study at a highly digital equipped school and only 20% to 25% of students are taught by digital confident and supportive teachers (European Commission 2013).

The promise of TEL has not really been materialised since today, especially in the domains of Higher Education and Schools Education. It is evident today that the history of learning technologies has documented many more failures than successes. The big promise of TEL (Technology Enhanced Learning), as technologies able to support the different learning processes in the life of people, by providing many choices to learning and removing the barriers to learning, including identification of competency gaps (what people don't know what they need to learn) has not yet materialized. Some primary examples of such failures

[12] HoTEL (HOlistic approach to Technology Enhanced Learning) was a Support Action of the 7th Framework Programme of European Commission, grant agreement no. 318530 *(October 2012 –September 2014).* http://hotel-project.eu/

include the disappointing efforts to support schools and HEIs with technologies and practices to share learning content and resources across institutions at a National and European levels. This vision of a federated European learning repository paradigm has not realised. Although several federations of repositories have been developed, scale up adoption has not happened yet, especially in schools domain. Furthermore, the goal to create and deliver personalized learning experiences to learners is also far from a reality. Unfortunately, although the recent developments in mobile, Internet technologies, social software, big data and intelligent agents and while research in those areas is beginning to show good results, especially in informal learning, and higher education (via MOOCs), we are still maybe a decade from affordable, flexible, powerful and personalisable learning technologies and environments able to make a big difference for the learners. Some better progress has been done in Professional learning. Today it is clearer how TEL can support professional learning, nevertheless, we are still agonizing to understand how learning resources can be planned and designed, found and re-used in the different contexts of Education and Training, and how the quality of learning that took place can be accessed via formal and summative assessment methods and can be certified. In addition, harmonization of learning standards that would allow for the needed interoperability among different systems and applications is far from achieved. In terms of linking learning to performance and employability, we are still facing big challenges, particularly in standardisation, in the area of competency, skills, and knowledge (Kamtsiou & Klobučar 2013). As suggested by a recent IPTS Report, a "policy recipe" for replication and multiplication of successful implementation does not exist, and 'one-size-fits-all' and 'one-off' models of innovation do not work in education. On the contrary, policies should encourage multiple and differentiated pathways to scale up innovation in 'organic' ways (Kampylis et al. 2013). Scaling up should be considered as a contextualized and organic process that allows for continuous change and adaptations in order to address, on one side the continuously shifting requirements of society and on the other the fast technological developments of our times. Along these lines, the policy priority of the European Commission (European Commission 2013) in terms of learning innovation is very clear: "Evidence indicates that the EU-wide experiences on innovative learning need to be scaled up into all classrooms, reach all learners and teachers/trainers at all levels of education and training. A full uptake of new technologies and OER requires more than boosting experimentations across Europe" (European Commission 2013, p.4). Clearly, the European Commission wants to go beyond experimentations, and to put in place the conditions for mainstreaming the meaningful and high-impact use of ICT for learning in all possible lifelong learning settings. In line with this policy objective, the European Commission is supporting a number of projects, which have the aim of fostering scalability of ICT-for learning (innovative) practices in Europe.

The need for a systemic approach

To add to these challenges, TEL is a complex eco-system, highly diverse across Europe, multi-disciplinary and with many players, with very different operating contexts, working in different cultures and under varying jurisdictions, with differing and sometimes opposite approaches to pedagogy and the task of education. Not only is the TEL Domain varied, the adoption of TEL and TEL products is also complex with many technical, pedagogical and organisational, social and political, interdependencies. Different providers of systems, content and services as well as their clients are mutually dependent and their alignment and collaboration is necessary in order to mainstream innovations. When organizations are looking to introduce and manage TEL innovations, they need to take into account the whole eco-systems in which they are operating. Consider for example how innovations from software designers and platform developers influence and impact the individual contexts of school teachers (teaching practices at schools, training needed to adopt the new systems, professional development) or those contexts of schools administrators and IT managers, where they need to make informed decisions on affordability, quality, and adoptability by existing organizational processes. These are systemic types of innovations that introduce changes to the whole system (Nascimbeni & Kamtsiou 2014), (Meiszner et al. 2014), (Kamtsiou & Nascimbeni 2013), (Kamtsiou & Olivier 2012) . Moreover, multiple root technologies, such as content delivery and assessment need to be integrated with other technologies that are found outside TEL, such as those related to Big Data, Intelligent Agents, mobile technologies and internet of things. These kind of technological innovations which are produced on the interface of several technologies are in turn giving birth to new pedagogical innovations, and new learning and educational practices, such as seamless learning, expansive learning, microlearning, rhizomatic learning to name a few (Millwood et al. 2013). Hence, these types of systemic innovations have “a nature of integrality” (Kaivo-oja 2011) and at the same time a nature of multi-diversity, since the applications envisioned usually require for different development pathways per involved technology. In addition, TEL innovations have a nature of expansion and change, which transforms both the learning practices and the communities themselves that adopt the innovation (Paavola et al. 2004). For example, in the school sector, according to (Engeström et al. 2002) there are several factors that make innovation in schools very difficult. These factors include social, spatial, and temporal structures embedded in classrooms, teachers’ culture of working in isolation, and political top-down governance.

Different providers of systems, content and services are often mutually dependent and a degree of coherence between them is necessary to transfer TEL innovations to the mainstream. Further, many other types of stakeholders such as educators, teachers, policy makers, administrators, parents have to come to agreement about what is wanted and how it should be provided. When organizations are looking to introduce and manage TEL innovations, they need to take into account the whole eco-system in which they are operating. The focus is on *desirable systemic change*, which means changes in: business (e.g. learning organizations); learning processes and practices (e.g. teaching, assessment); technologies (e.g. software, and tools and infrastructure) and social changes (e.g. role of learning in developing European citizens, their employability, and personal fulfilment). At the same time TEL innovations can also be regional, national and at European levels. Education in Europe varies widely, with different cultural, governance and pedagogical, legal systems, so any attempt to articulate a single European level vision and roadmap for TEL is not going to work. Therefore, any kind of shared strategic perspectives and/or roadmaps needs to be negotiated and contextualised at national and regional levels. Government agencies, from local, through regional to national, as well as school decision makers from heads to the teachers involved also need to come to some level of agreement for an innovation to be mainstreamed. Similar problems are faced by companies operating in the TEL domain in Europe that often focus on particular nations or groups of nations (Nascimbeni & Kamtsiou 2014). Thus, micro - company level roadmaps presuppose a limited environment or their roadmap focuses only on generic technologies, but they then necessarily miss out on the co-innovators and other players, who are needed to complement and/or adopt the technology in order to bring it to particular markets (Kamtsiou, Olivier, et al. 2013).

Therefore a single desired future for TEL should not be presupposed, but several futures some of which may be informed by shared strategic perspectives that are negotiated at national and regional levels. Even where a single desired future is established for a given set of players, if they span more than one educational system, the roadmap for that desired future may well have to be adapted for each, and further, as each educational system may evolve differently in response to wider political, economic and social pressures, the roadmaps would have to be adapted to these changes also. Dynamic processes are especially needed in highly turbulent times, such as we have today, as well as in areas undergoing rapid and continuous change, particularly in technology-based areas such as TEL. In circumstances like these, for any roadmap to remain relevant, it has to be capable of being continuously up-dated and able to evolve over time. It should be supported by planned research activities for managing the long-term innovations, as well as policy actions (Kamtsiou, Olivier, et al. 2013).

Talking about innovation in learning implies the need to consider not only innovation processes, but also (and mainly) the significance of the interconnection of the actors involved in the processes of innovation. In other words, the complex ecosystem of TEL stakeholders shall be considered when defining TEL innovation. HoTEL project characterised TEL innovations similarly to the innovations defined by the Society Driven Innovation Study developed in the frame of the INNO GRIPS Project – Global Review of Innovation Intelligence and Policy Studies (Rigby et al. 2008), cited in (Aceto et al. 2014)), (Nascimbeni & Kamtsiou 2014). The Study considers innovation as a systemic process where societal needs are met through the complex interaction of actors engaged in meeting socially defined needs. According to the Study, "Society Driven Innovation (SDI) is innovation where: (i) the objective is something other than just the narrow economic goals of competitiveness and economic growth. Rather, it is to meet some sort of social or cultural need; (ii) This 'societal need' is defined by society (usually through the government acting as 'the voice of the people); (iii) Government policy is deliberately oriented to this objective – and this is the primary goal of the research or innovation programme (not just a hoped-for spin-off)"(Rigby et al. 2008).

Motivation and the context of "creative classroom" theme

The fundamental transformation of education and training has been acknowledged as a key driver in Europe's 2020 strategy in order to successfully deal with the current economic crisis and systematically support European competitiveness. Towards this end, sustainable innovation in education and training is of paramount importance and is addressed in several key initiatives in Europe 2020 strategy (e.g. Agenda for New Skills and Jobs, Youth on the Moreover, the Digital Agenda, and the Innovation Union Agenda (Bocconi et al. 2013b), (Bocconi et al. 2013a), (Kampylis et al. 2012), according to Directorate-General Education and Culture (DG EAC) of European Commission research and practice so far show that there is an implementation gap between ICT potential and its actual use in formal and non-formal education. While ICT is well mainstreamed outside schools, formal E&T is only in its early adopter's stage. In order to fill this gap, the European Commission has launched the *"Creative classroom"* initiative, aiming to support the mainstreaming of innovation in learning and teaching, and provide a systemic impact in Education. This new initiative is linked to Europe 2020 & ET2020 objectives (Bocconi et al. 2013b).

Major motivation behind this initiative was:

a) the realisation that the existing small-scale, innovative projects produced *little systemic impact* in school education practices, often not continued beyond pilot or funding schemes, and lacking any post-evaluation of outcomes, effectiveness and efficiency. The commission hopes that the "creative classroom initiative" will provide a better understanding of how ICT-enabled innovation for learning can be brought to scale and/or have systemic impact.

b) The *high unemployment level* in young people necessitates a complete transformation of the current educational systems and how people learn from very early childhood education.

What is meant by the term creative classroom? DG EAC commissioned a large 3 years study on "Up-scaling Creative Classrooms in Europe" (SCALE 2009) launched by the Information Society Unit at JRC-IPTS1 in December 2011. According to JRC report (Bocconi et al. 2012): Key Elements for Developing Creative Classrooms in Europe "Creative Classrooms are innovative learning environments that fully embed the potential of ICT to innovate and modernise learning and teaching practices. In CCR, open education principles are fully implemented in practice, at all levels. Curriculum and content are open, providing learners with concrete opportunities for developing 21st century skills, such as problem-solving, inquiry, collaboration, and communication. Learning is flexible and engaging, meeting students' individual needs and expectations. Leadership is open and participatory, supporting teachers/educators' innovative practices. (e-)Assessment paradigm now reflects the core competences needed for life in the 21st century. 'Creative Classrooms' (CCR) are conceptualised as innovative learning environments (in formal and informal settings) that fully embed the potential of ICT to innovate and modernise learning and teaching practices". A survey of Schools carried out for the European Commission (DG Communications Networks, Content & Technology) by European SchoolNet during the school year 2011-2012, revealed that: "teacher participation in ICT training for teaching and learning (T&L) is rarely compulsory. At EU level, depending on the grade, only around 25-30% of students are taught by teachers for whom ICT training is compulsory. This appears to contrast with teachers' appetite and interest in using ICT, as shown by the large majority of them who choose to develop their ICT-related skills in their own spare time. Interestingly, around 70% of students at all grades are taught by teachers who have engaged in personal learning about ICT in their own time. Although online resources and networks are widely available in Europe, they are a relatively new way for teachers to engage in professional development, and only a minority of these opportunities are used by schools" (European Schoolnet 2013). Systemic impact and mainstreaming of ICT innovation in schools is a key focus of the creative classroom initiative. As stressed by Yves Punie (IPTS) during his keynote in the 'European Forum on Learning Futures and Innovation: The role of technologies, the challenges of scalability and mainstreaming', "scale and sustainability in school's education: Is about innovative practice that meets the requirement of digital society and economy; is about impact and systemic change (that is cost-effective); is about what works and what does not work (implementation); is about a flexible, dynamic, context-specific model with local autonomy and shared ownership" (Punie et al. 2009).

4.2.2 Case Study duration and time horizon of the produced roadmap

TEL-Map project lasted two and a half years *from October 2010 – May 2013*. The Roadmapping exercise referring to schools sector took place during the second year of the project. During the first year the main emphasis was in designing and developing a service portal[13] in order to host the observatory function and an internal web-service for the co-innovation group. In the first year, the focus was also in cartography activities. During the second year, the co-innovation group was formed from TEL stakeholders. Due to the currently turbulent environment, and the fast technological changes, the co-innovation group decided that it would not be effective to plan longer than *seven years* for schools sector. This included strategy and implementation. Therefore, the time horizon of the roadmap was seven years.

4.2.3 Participants

TEL-Map project: Roadmapping and intelligent network facilitation team

TEL-Map project comprised a consortium of *10 European partner institutions,* seven from Higher education, two companies and one governmental organisation. Three of them formed the roadmapping facilitation team, headed by the author and the other seven were working on developing the website and implementing the observatory function. The author provided the web space mock-ups designs and the conceptual framework for the observatory function. In addition the author together with one more partner composed the modelling team which was responsible for the observatory modelling activities, e.g. Conzilla, CmapTools and also supported and managed the modelling activities of the co-innovation group and the PhD students' network. Each European institution had at least 2 people working on the project.

'Dynamic Roadmapping' co-innovation group

The roadmapping co-innovation group was comprised of 134 members, from 19 European countries (AT:4, AU:2, BE:13, BG:1, CZ:1, CZ:1, DE:16, EE:1, ES:5, FI:5, FR:8, GR:14, HU:1, IE:3, IT:12, OUNL:8, NO:2, PO:1, RU:1, SE:3, UK:31). The co-innovation group had also close collaboration with VISIR policy network, HoTEL TEL innovation support network, STELLAR research Network of Excellence and ODS large scale implementation project in schools sector. This included co-location of events, sharing of stakeholder networks, as well as analysis and results. The development of the co-innovation group, started as a top-down approach, with the the project partners approaching the first few members in collaboration with the European Commission. In practice the group soon became autonomous and used a mixture of top-down and bottom-up approaches in order to: a) clearly capture, and explore the different stakeholders' expectations about present and future requirements in European schools and to b) form and enhance the co-innovation group. The co-innovation group comprised a multi-disciplinary group of TEL stakeholders, which aimed to bring all necessary actors together in order to plan and implement the school's sector roadmap. The group shared its insights on past and current TEL, and at its thinking on TEL

[13] Learning Frontiers portal: http://www.learningfrontiers.eu/

futures, so that a) all TEL networks can benefit from complemented capabilities of participants in TEL communities and their insights, and b) plan and implement the innovative developments themselves and for themselves, therefore c) spread and adopt the innovations more rapidly. It was also supported by an intelligent network, and a portal which was developed by the partners responsible for the observatory function in the project. A detail analysis of the formation of the co-innovation group is provided in section 6.2.

Membership issues

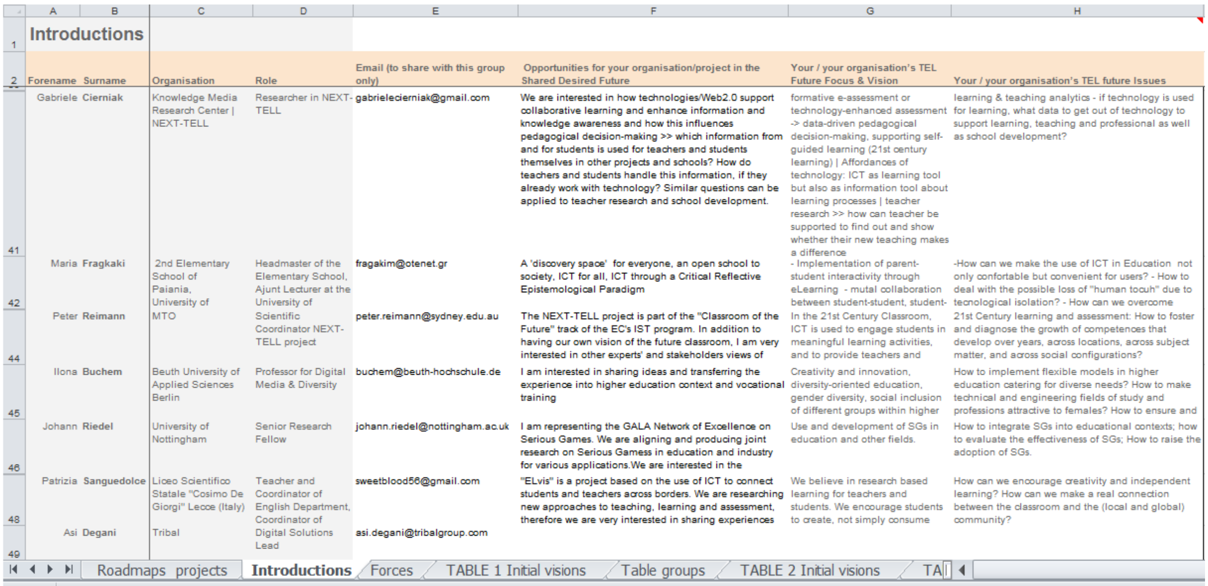
The co-innovation group in TEL-Map was an open system, which was enhanced by new members dynamically. The co-innovation group could invite new members at any time of the process, including associates from their own networks and from other innovative communities which were identified via intelligence provided by the observatory cartography function.

The group used a Google document to openly collaborate and assign new members. Members were asked by the roadmapping facilitation team to register themselves and share initial information about their name and email, the name of the organisation they represent/work for, their role in the organization, some first insights about theirs/their organisation's TEL Future Focus & Vision, and theirs/their organisation's TEL future issues (see Figure 85). They were also asked to share some innovation milestones or events that they thought they shaped the domain of TEL. In this way, the members already got a shared history and a first mapping of their activities, interests, and visions. Later on, after the members defined collectively their shared visions as a co-innovation group, they were asked to add in the google document the opportunities for their organisation/project in this shared desired future. Google documents were used since, they allowed logins, they were tools familiar to all members, and they allowed collaborative editing.

The protocol for inviting new members is presenting in the following table 10:

Protocol for new members	
Step	**Comments**
An invitation for a new member could come from the co-innovation group, the intelligence observatory team (e.g. suggestions from the cartography), or from the stakeholders themselves.	Balance may be maintained by ensuring the update and representation of the different stakeholder categories and maintain the focus of the co-innovation group (e.g. on transforming schools)
The co-innovation group is informed about the new candidate and decide on whether to join the group.	Provides access to all tools, content, and infrastructure
The roadmapping facilitation team, invites the candidate to familiarise themselves with the process, and results so far, and they respond to questions of clarification	Communication with new members and the facilitation team is done via skype and pointers to the GoogleDoc Workspace
The new candidate uses the co-innovation's Google documents in order to identify their future focus and potential for action in their context	
They are asked to read the desired futures, the emerging shared desired future(s), and roadmaps outlined by the co-innovation group and offer their response, alignment and potential opportunities for contributions in the respective google document pages	Provide alerts on this information to the co-innovation group. The new member is contacted from the facilitator assigned to the particular vision, roadmap, roadmap output, etc.
A suggestion comes from the facilitator to contact the sub-group that the new member best align with in order to introduce themselves to that sub -group in an email	Announcing their membership
5. Invite them to the next face-to-face meeting and online consultation meetings	

Table 10. membership protocol



Introductions

Forename	Surname	Organisation	Role	Email (to share with this group only)	Opportunities for your organisation/project in the Shared Desired Future	Your / your organisation's TEL Future Focus & Vision	Your / your organisation's TEL future Issues
Gabriele	Cierniak	Knowledge Media Research Center | NEXT-TELL	Researcher in NEXT-TELL	gabrielecierniak@gmail.com	We are interested in how technologies/Web2.0 support collaborative learning and enhance information and knowledge awareness and how this influences pedagogical decision-making >> which information from and for students is used for teachers and students themselves in other projects and schools? How do teachers and students handle this information, if they already work with technology? Similar questions can be applied to teacher research and school development.	formative e-assessment or technology-enhanced assessment -> data-driven pedagogical decision-making, supporting self-guided learning (21st century learning) | Affordances of technology: ICT as learning tool but also as information tool about learning processes | teacher research >> how can teacher be supported to find out and show whether their new teaching makes a difference	learning & teaching analytics - if technology is used for learning, what data to get out of technology to support learning, teaching and professional as well as school development?
Maria	Fragkaki	2nd Elementary School of Paiania, University of	Headmaster of the Elementary School, Ajunt Lecturer at the University of	fragakim@otenet.gr	A 'discovery space' for everyone, an open school to society, ICT for all, ICT through a Critical Reflective Epistemological Paradigm	- Implementation of parent-student interactivity through eLearning - mutal collaboration between student-student, student-	-How can we make the use of ICT in Education not only confortable but convenient for users? - How to deal with the possible loss of "human tocuh" due to tecnological isolation? - How can we overcome
Peter	Reimann	MTO	Scientific Coordinator NEXT-TELL project	peter.reimann@sydney.edu.au	The NEXT-TELL project is part of the "Classroom of the Future" track of the EC's IST program. In addition to having our own vision of the future classroom, I am very interested in other experts' and stakeholders views of	In the 21st Century Classroom, ICT is used to engage students in meaningful learning activities, and to provide teachers and	21st Century learning and assessment: How to foster and diagnose the growth of competences that develop over years, across locations, across subject matter, and across social configurations?
Ilona	Buchem	Beuth University of Applied Sciences Berlin	Professor for Digital Media & Diversity	buchem@beuth-hochschule.de	I am interested in sharing ideas and transferring the experience into higher education context and vocational training	Creativity and innovation, diversity-oriented education, gender diversity, social inclusion of different groups within higher	How to implement flexible models in higher education catering for diverse needs? How to make technical and engineering fields of study and professions attractive to females? How to ensure and
Johann	Riedel	University of Nottingham	Senior Research Fellow	johann.riedel@nottingham.ac.uk	I am representing the GALA Network of Excellence on Serious Games. We are aligning and producing joint research on Serious Gamess in education and industry for various applications.We are interested in the	Use and development of SGs in education and other fields.	How to integrate SGs into educational contexts; how to evaluate the effectiveness of SGs; How to raise the adoption of SGs.
Patrizia	Sanguedolce	Liceo Scientifico Statale "Cosimo De Giorgi" Lecce (Italy)	Teacher and Coordinator of English Department, Coordinator of	sweetblood56@gmail.com	"ELvis" is a project based on the use of ICT to connect students and teachers across borders. We are researching new approaches to teaching, learning and assessment, therefore we are very interested in sharing experiences	We believe in research based learning for teachers and students. We encourage students to create, not simply consume	How can we encourage creativity and independent learning? How can we make a real connection between the classroom and the (local and global) community?
Asi	Degani	Tribal	Digital Solutions Lead	asi.degani@tribalgroup.com			

Figure 71 A snapshot of Members information from the Google document shared by the co-innovation group

Once the members were registered at the Google document they were provided a login account and with access to the internal web space at the portal (see Figure 72). The internal space of the portal[14] organised the outputs of the co-innovation group and also suggested and listed external intelligence from the observatory that related directly to their school's domain, for example, other roadmaps (past and current), future scenarios, networks that work on the same domain, their outputs, related upcoming events, etc.

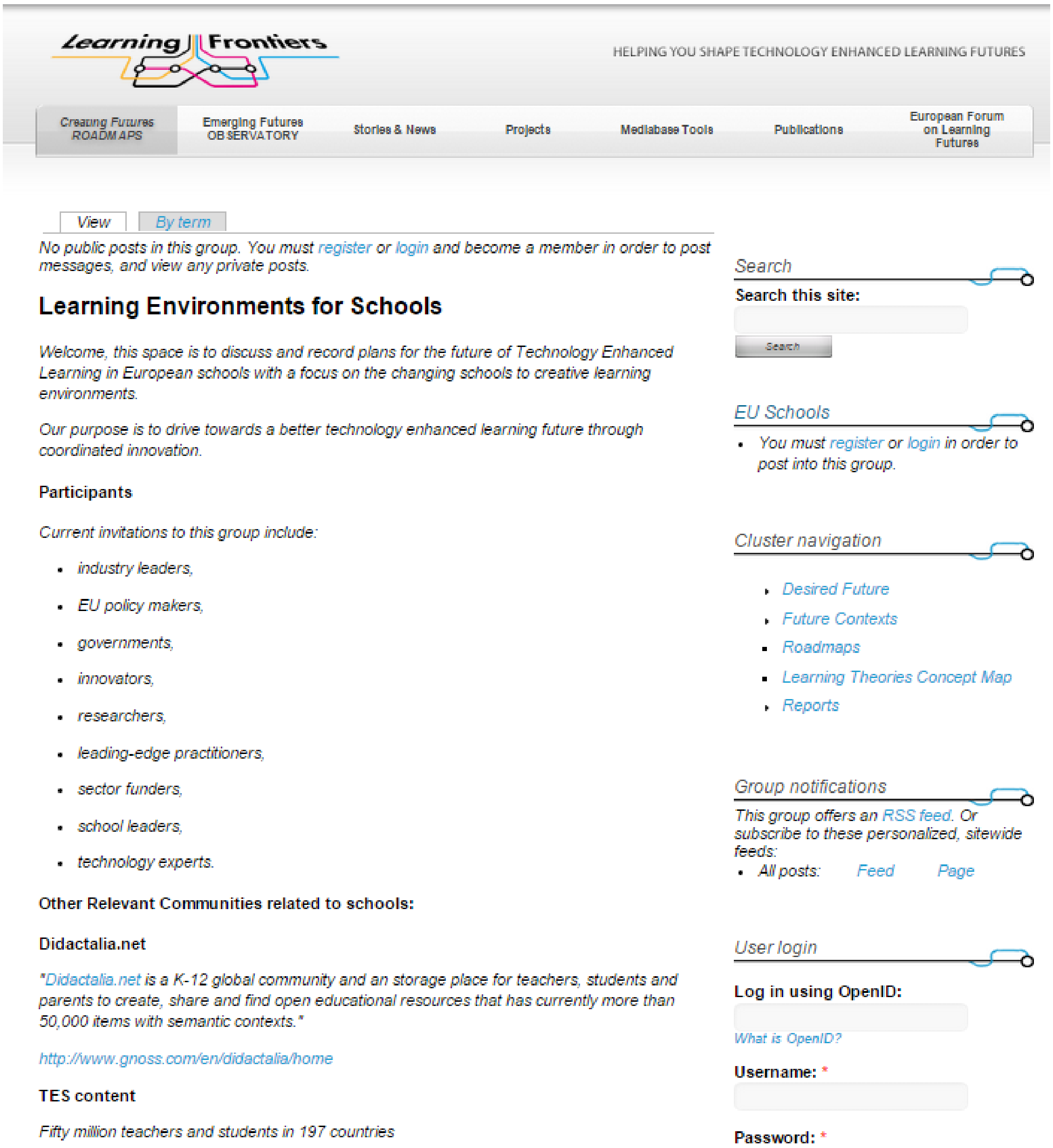


Figure 72. Snapshot of the Co-innovation internal web space at learning frontiers portal

14 http://web.archive.org/web/20150212211813/http://www.learningfrontiers.eu/?q=content/eu-schools

Intelligence network: Observatory function

This capacity-building of innovative TEL communities, which formed the co-innovation group, was supported by an *intelligent network* of community representatives in order to empower them to better discern and interpret what is going on within other participating TEL stakeholder communities (capturing the voice of TEL communities), and to share and exchange knowledge with these communities in order to take advantage of emerging trends and developments in TEL, and tensions of which they might not yet be aware of. In addition, an observatory function was developed and a portal to classify and present the results. Activities such as surveys, weak-signals analysis, Delphi studies, bibliometric, Social Networking Analysis, gap analysis, interviews were part of the observatory function. The intelligent network started with the project participants and quickly expanded with members of their networks and associates. Seven of the project participants were responsible to monitor the work of the intelligent network as gate keepers and the activities related to the co-innovation portal (http://www.learningfrontiers.eu/). A detail analysis of the observatory function, methodologies and tools is provided in the case study below in sections 6.3, 6.4, 7.2.2)

Top down –versus bottom up approach to 'Dynamic Roadmapping'

Two tensions have been identified in terms of the approach to stakeholder engagement in roadmap building, and have been examined and operationalized accordingly: the *top-down* or "invited" approach, involving mainly the *Future Search Methodology* (convergence – common vision – collaboration towards common vision); and the *bottom-up*, emergent approach employing mainly bottom-up domain mapping methods (cartography, disagreement management, divergence). The second approach focused on mapping the domain of TEL and technological developments around TEL, including the innovative communities that investigated these technologies. Thus, capturing, externalizing, aggregating and contrasting the views of communities aiming to collaborate. Overall risks are managed and minimised by having integrated these two approaches.

4.2.4 Methods and tools used

Table 11 classifies the various activities, methods, and the respective tools, which were used during the case study. It also classifies the activities according to the roadmapping level (micro, meso, macro) and the types of participants involved in the activity.

Activity name Roadmapping Level participants	Method	Instruments/Tools
Strategic Conversations (competitive Intelligence) Macro Level Observatory network	• Cartography, Activity mapping: "Capturing voices of" TEL communities • Conceptual Modeling • Disagreement/discourse management, semantic ontologies and vocabularies • Social Networking Analysis	Observatory intelligence infrastructure, Conceptual Modelling tools (Confolio, Conzilla, CmapsTools), Media Base and Social software tools, e.g. web 2.0 applications (Facebook, Tweeter-Feed/Widget, linked in, RSS feeds), Questionnaires, interviews, TEL

	• Surveys • experts workshops, stakeholders consultations • Desktop analysis of scenarios, and roadmaps of innovative TEL communities • TEL R&D projects analysis • Crowdsourcing, co-innovation formation • Future Search ARE-IN.	research projects analysis and semantic templates, learning cafes and stakeholders consultations at TEL events (e.g. conferences, summer schools, workshops, industry events), Delphi tools, online Delphi, Social Network Analysis tools - MediaBase tools: PESTL Classifier, blogosphere search, Crunch, D-VITA, LF Dashboard, crowdsourcing. Researchers, organisations, research profiles
Market Intelligence Micro (company level) Macro (industry level) Observatory network Industry participants	• Market analysis and user requirements, state of play • Desktop analysis • Literature review • Market relevance analysis of the co-innovation roadmaps • Gap analysis • Portofino of solutions • Workshop 3: Industry perspective.	Observatory intelligence infrastructure, participation in Trade fairs for example: (e.g. EC-TEL, EdMedia, ICALT, AeLC, Echallenges 2011, Learning futures festivals conference, Learning Without Frontiers – Festival & Conference 2012 etc., OnlineEduca, etc.), interviews with industry experts, and TEL stakeholders, Questionnaires & online surveys, Industry Market analysts reports such as: (Ambient Insight Comprehensive Report, The NMC Horizon Report: 2011 K-12 Edition, Ambient Insight's 2011 Learning Technology Research Taxonomy, Cegos - Training Styles in 4 European Countries, Cisco - Multimodal Learning through Media: What the Research says, UCISA - 2010 Survey of Technology Enhanced Learning for higher education in the UK, Gartner - Hype Cycle for HCM Systems, Ambient Insight's Mobile Learning Report). Consultation workshop with industry players, learning café workshop.
Learning Intelligence Micro level (learning technologies) Observatory network	• Learning paradigms and new learning practices identification • literature review • Weak signals analysis for new forms of learning • PESTLE analysis • Delphi • Grass-roots learning innovations survey as good practices	Observatory intelligence infrastructure, Interviews, Literature reviews (e.g. Technology Horizon reports, academic journals/ databases), Delphi Tool and analysis, MediaBase tools: PESTL Classifier, blogosphere search, Crunch, D-VITA, LF Dashboard, crowdsourcing.
State of the Art (technology intelligence)	• Technology review • Technology assessment • Technology readiness	Observatory intelligence infrastructure, Questionnaires, surveys, modeling tools,

Macro level Observatory network TEL providers & TEL researchers	• Technology adoption-lifecycle curves • Stakeholders consultations • Existing roadmaps review • Data analytics, PESTLE	TEL-based trade fairs, market analysts reports, PhD students network, topic analysis, bibliometric tools at the portal, MediaBase tools: PESTL Classifier, blogosphere search, Crunch, D-VITA, LF Dashboard, crowdsourcing. TEL-related research and technology futures projects (such as iTEC, STELLAR, VISIR, Beyond Current Horizons, DynaLear, futureICT, GRDI 2020), Intermediaries such as London Knowledge Lab, UK TLRP, IBM Center for Service Science, Research Council Research Fellow- Australia, AIED Society etc.), ASTD US, ELIG, etc. Research funding frameworks JISC UK - Technology Enhanced Learning, UK teaching and learning research programme.
Identify Forces of change Macro level Observatory network Co-innovation Group	• Foresight, PESTLE, Horizon scanning, Delphi, weak signals analysis • Topic/text mining (Nave method) • Trends identification focus groups, experts workshops • Crowd sourcing • Workshop 1: shared perspectives • Workshop 2: Context scenarios	Observatory intelligence infrastructure, co-innovation infrastructure, Interviews, Delphi tool, mining tools such as blogosphere search, Trend analyser, network social analysis tools, bibliometric (e.g., MediaBase tools, PESTL Classifier, Crunch, D-VITA, and LF Dashboard), crowd sourcing tools, Discourse management, mind-mapping tools for clusters, Google Docs. Learning café workshop.
Level of Impact Degree of Uncertainty Macro level Observatory network Co-innovation Group	• Foresight • Trends and Weak Signals analysis in terms of expectancy to occur and impact • Experts based workshops, Polarizing, Ranking • Crowdsourcing, annotations, commenting • Mapping Conceptual modelling • Workshop 1: shared perspectives	Observatory intelligence infrastructure, co-innovation infrastructure, Delphi tool, workshops, Discourse crowd sourcing, Google Docs, learning cafe.
Desired Futures Meso level Co-innovation Group	• Future Search • Opinion polling and focus groups • Learning cafes • Mapping/Conceptual modelling • Online consultation meetings • Workshop 1: shared perspectives	Dynamic Roadmapping infrastructure for co-innovation group (based on Future Search), co-innovation Future Search Event, Conceptual Modelling tools (Confolio, Conzilla, CmapTools), Google Docs, online stakeholders consultations,

		learning cafes.
Future Contexts Macro level Observatory network	• Foresight, Context scenarios • Delphi scenario planning • Context scenario Matrix • Literature review • Mapping • Workshop 2: Context Scenarios	Observatory intelligence infrastructure, Delphi tool, clusters, web-portal, Google Docs, learning cafe on Context scenarios.
Testing your Visions Meso level Co-innovation group	• What if analysis, stress-testing against context scenarios • Cross impact analysis • Wild cards, weak-signals • Mapping, disagreement management • Workshop 5: Stress-testing initial roadmaps	'Dynamic Roadmapping' infrastructure for co-innovation group, Observatory intelligent network infrastructure, context scenarios, online stakeholders' consultations, learning café.
Gap analysis Meso level Observatory network Co-Innovation group	• Roadmapping • State of the art analysis • SWOT analysis, technology assessment, technology readiness and adoption • Workshop 4: initial roadmaps	Observatory intelligence infrastructure, Conzilla / CmapTools or other modelling tools, templates, topic mining, interviews, surveys, technology lifecycles, State of the art analysis, technology SWOT, learning cafe.
Roadmaps and short, mid, long term action plans. Meso level Co-innovation group Micro Level At individual members' levels	• Portfolios, strategic planning • Roadmapping • Charts • Workshop 3: Industry Perspective • Workshop 4: Initial Roadmaps	'Dynamic Roadmapping' infrastructure for co-innovation group, Conzilla / CmapTools, Google Docs, learning cafes, online stakeholders' consultations, Learning café.
Assessment of Roadmapping Artefacts Meso level Observatory network Co-innovation Group	• Roadmapping • Change and adoption management • Weak signals collection and analysis, wild cards, Real-time Delphi, cross impact • Workshop 5: Stress-testing Initial Roadmaps	Observatory intelligence network infrastructure, Real-Time Delphi tool, Google Docs, co-innovation blueprints (Adner's model), learning café.
Roadmaps updates Meso level Observatory network Co-innovation Group Individual co-innovation members plans (micro levels)	• Roadmapping monitoring • Foresight • SWOT • Gap Analysis • Workshop 5: stress testing initial roadmaps	Observatory intelligence network infrastructure, 'Dynamic Roadmapping' infrastructure for co-innovation groups, CmapTools, Google Docs, learning cafe.

Table 11: Summary of methods and tools in co-innovation roadmapping process

4.2.5 Organizational structure of the 'Dynamic Roadmapping'

Figure 73 shows the relationships between the TEL-Map team and the other actors in the co-innovation eco-system. It also provides an organizational structure of the key roles, relationships and groupings to support 'Dynamic Roadmapping'.

The facilitation group initiated and supported the co-innovation group. It sets up the initial co-innovation group and provides administrative support, such as planning and organizing the differed workshops, provide online support with specific online collaboration and modelling tools and virtual spaces. It also managed the observatory and the interactions between the co-innovation group and the observatory. The size of the team was a small size of three individuals headed by the author, who had the overall Roadmapping Manager role and who provided the process framework.

The observatory group headed by the researcher formed the *intelligence network* that supported the co-innovation group and facilitation team in their roadmapping process by providing them with new intelligence and analysis in order to make informed decisions. The external to the ***Observatory Intelligence Networks*** were other networks, research projects, and communities, who were collaborating with the roadmapping groups and were managed by the Gate Keepers and the Pathfinders of the Observatory group. In order to collect, organize, and analyse the information a network of people needed to be in place (see figures 73).

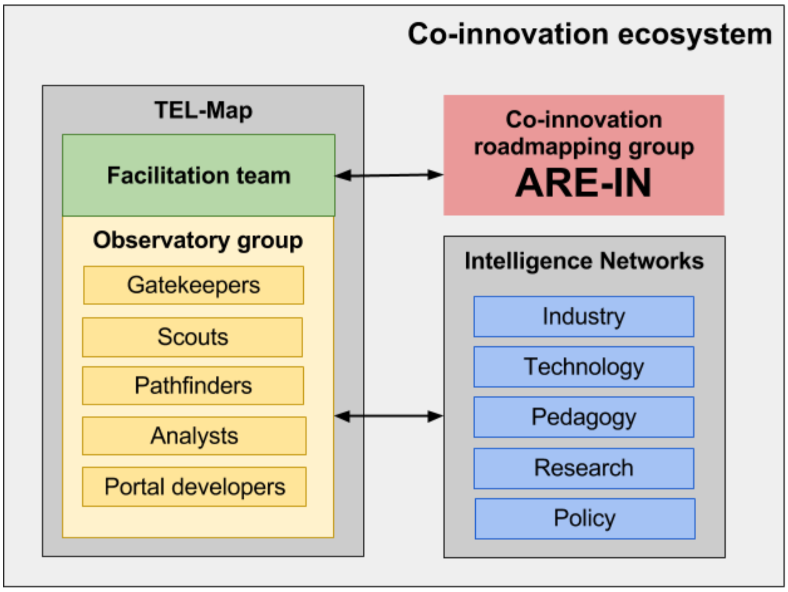


Figure 73. Organizational structure of 'Dynamic Roadmapping'

The Observatory roles are described below:

Gate Keepers: people responsible for managing specific observatory areas and for categorizing information. They are also act as portal content managers. Usually, some of the key Gate Keepers were also taken part in the facilitation group, when necessary. In this case, 7 people from the project partners.

Scouts: people who seek out new ideas, and weak signals. They are typically appointed by the Gatekeepers. These included a large network of PhD students in collaboration with the EA-TEL summer school and Doctoral consortium of young researchers in TEL, who could both scout for new technology developments, as well as produce cartographies for TEL key research areas and dominant research actors, and their offerings.

Analysts: people who make sense and analyse the intelligence information, classify it and reported it to the gate keepers. These were people from the TEL-Map project and experts from the co-innovation group.

Pathfinders: people who had connections with networks, experts, and intermediaries. They could suggest scouts to Gate Keepers as well as information sources. These were any associate or expert in TEL.

Portal developers: people who work with Gate keepers to add information intelligence at the portal. These were mainly 4 project partners from TEL-Map project.

Strategists: Comprise the co-innovation group and other Tel-Map partners, who process and synthesize the information. They work with Gate keepers and the co-innovation group in order to specify information needs and manage interactions with experts and actors in TEL domain. This group was headed by few senior scientists/researchers, technology, pedagogical experts and industry players who were partners in TEL-Map project.

Modelers: People who model and map the results from cartography and create the domain maps. They interact and sometimes are part of the facilitation group and support the co-innovation groups. They provide their outputs to analysts in order to assess how they affect the future of TEL. These activities were headed by people from Tel-Map group headed by the researcher, some people from the intelligent network and people from the co-innovation group. Data is collected through multiple means such as interviews, observation, archival records and other documentary evidence (Eisenhardt, 1989).

Workshops' protocol

Five milestone workshops were organised in order to implement the Dynamic roadmapping framework. The first two, 'Shared Perspectives' and 'Context Scenarios' followed the Search Conference format. Workshop 3 and 4 were organised as learning cafes followed a customised roadmapping format. Workshop 5 Stress-testing initial roadmaps was organised as a foresight consultation event. The formats of the workshops and activities are discussed in detail in Case study Section 6.5.

All workshops followed the following protocol. They were organised according to learning café principles. This working method is known as "learning discussion forum" or "Learning Café", and has been successfully implemented in a number of events involving European experts. This group dynamics technique was initially developed by Juanita Brown and David Isaacs (MIT). The knowledge creating process SECI, conceived by Nonaka and Takeuchi, was later adapted and added to the learning café methodology by Leenamaija Otala. According to SECI model the KEY to KNOWLEDGE CREATION lies on the 4 modes of KNOWLEDGE CONVERSION, which occur when tacit and explicit knowledge interact with each other. These four modes of knowledge conversion are socialization, externalization, combination and internalization. The SECI theory was cornerstone in the development of the Dynamic Roadmapping model see (section 3.1). The Café is built on the assumption that people already have within them the wisdom and creativity to confront the most difficult challenges. Learning café events are informal. Successful socialization and externalization of tacit knowledge requires a right mix of stakeholders and experts from various backgrounds and a hospitable atmosphere that promotes trust and commitment. The working sessions are interactive and demanding. Participants' best equipment is relaxed mind and willingness to get involved in mind rewarding experiences. Bring with them their positive attitude and your wishes for the future world.

The learning cafe participants are engaged in highly interactive, structured sessions formed around specific themes. Each theme is introduced by an expert, giving a short presentation to raise awareness on the main issues to be discussed. Then, the participants are divided in small groups sitting around tables and each group discusses each theme, or select the ones that feel closer to their interests and expertise. The participants are using the papers and pens on the tables to write down their ideas and sticker notes. Each table has a facilitator that reports briefly on the table discussions at the end of each session. At the end of the two sessions a panel discussion follows, presenting the key outputs of the sessions.

In this research, the learning café methodology was enhanced with **conceptual modelling** which took place during and after the events, using collaborative modelling tools e.g. Conzilla browser and CmapTools. The facilitators were responsible for continuing and facilitating the discussions online and for the orientation of new members in the co-innovation group.

Guidelines for the organisation of learning café to the facilitation team

- Introduce the theme to the participants using PowerPoints or other supportive materials.
- Formulate powerful questions that stimulate the discussion
- Questions should be provoking, focus on inquiry, challenge assumptions, open new possibilities and evoke more questions.
- During the discussion move among the tables (small groups), but try to avoid dominating the discussion.

Table Facilitator's guidelines

- Remind and help participants at your table to write or draw down key connections, ideas, discoveries, and deeper questions as they emerge.
- Encourage everyone to participate. The aim is to connect diverse people and ideas. You may want start the discussion by a round table, during which each participant will express their first ideas.
- Remain at the table when others leave and welcome the newcomers from other tables.
- Briefly share the key insights from the previous group conversation so that the newcomers can link and build using ideas from their respective tables.
- After the session post the key findings (jotted on tablecloth) on the wall and be prepared to present during the reporting session.

Etiquette of the learning café

- ✓ Focus on what matters.
- ✓ Contribute your thinking and experience.
- ✓ Speak from the heart.
- ✓ Listen to understand.
- ✓ Link and connect ideas
- ✓ Listen together for deeper themes, insights and questions.
- ✓ Play, doodle, draw, and write on the 'tablecloths' (paper)!

Improv Goals were added in between sessions in order to break the ideas, to enhance the collaboration between the participants. The method used was developed by ISKME[15] . The researcher and one more person were trained in a special 7 days training event by ISKME facilitators in order to learn the ISKME Improv and process. The researcher had also an extensive experience of more than 12 years of organising and running local, European and international learning cafes with experts. These Improv helped:

- To give participants tools for collaboration—new ways of being together.
- To help them see that they individually don't have to have "The Amazing Idea", that that can be discovered.
- To have them experience "Yes, And…" as a technique to achieve this.
- To build trust within their groups

Tenets of Improv:

- Suspend judgment (Stay present—evaluate later)
- Let go of your agenda/be flexible (Be open, see your partner as brilliant)
- Listen in order to receive (Listen for where you agree or can support)
- Build on what you receive (Connect and move forward WITH your partner)
- Make your partner look brilliant (Focus outward. Build on what they say.)
- Look for connection/what you can accept
- Serve the scene. (Serve the bigger picture)

Milestones events

The main activities (at micro, macro, meso levels), the methods and instruments used in this case study are listed in table 11.

Milestone - Event	Type of Participants	Format type Roadmap level	Role of researcher
Literature review findings 30/6/ 2011	Researcher	Gaps, Analysis, Research questions, models *(macro level)*	Performed State of the art review in: Foresight, Roadmapping, Innovation models. About 320 papers were reviewed and common features, gaps and issues in the current practices were identified.
Conceptual model and processes of Dynamic Roadmapping (version 1)	Researcher	Conceptual model Text description, conceptual models, process framework *(meso level)*	The researcher produce the model based her observations from her field work (15 years) and literature review analysis.

[15] ISKME Institute for the Study of Knowledge Management in Education http://wiki.oercommons.org/mediawiki/index.php/Improv

30/8/2011			
Think Tank workshop at EC-TEL 2011, Palermo, Italy 21/9/11 1st capturing the voice of TEL communities event Engagement TEL stakeholders communities in Co-Innovation group	Researcher Roadmap facilitation team TEL experts, Policy Makers, Researchers, teachers, publishers, Technology experts	Workshop Conceptual Models *(macro level)*	The researcher organised a dedicated Roadmapping session within the Think Tank workshop (Agenda, presentations, coordination) Programme committee member Co-Modelling of results (2 people); Event was a) the starting point for TEL Cartography and mapping of strategic Conversations b) Initial list of experts to be engaged in co-innovation group; Assisted in alignment (clustering, collaboration, discussion, modelling and disagreement management within TEL communities)
Observatory Function Deployment Development of Portal and collaboration web spaces (e.g. electronic portfolios, Conzilla, CmapTools, Google Documents) Version 1: 30/9/11 Version 2: 5/5/12	Researcher Observatory Network Developers 7 core people managed plus the researcher Observatory Network was substantially connected to other people from Research, Industry, Practice	Report on Conceptual Observatory Framework Observatory function Web Portal/ Co-innovation web spaces Conceptual Modelling Tools *(Macro)*	-The researcher developed the Technology Intelligence framework for the Observatory function and Portal (and produce relevant report; She also developed the specifications requirements related to a) Macro activities (external) and b) Co-innovation's group (internal); -Developed the Portal Mock-ups; -Managed and coordinated the Observatory work, reports, and roles (e.g. assignment of Gate Keepers, Modelers, Analysts, Scouts, etc.) -Led the collaboration activities with Observatory Network in order to share insights, models, processes and tools for creating the Observatory function and web spaces for the Co-innovation group.
Creation of ***metadata profiles*** templates for Research Projects, ***Interviews templates*** for TEL adopters and TEL providers questionnaires 28/09/2011	Researcher Observatory (assessment of templates and interview questions)	Templates Meta data profiles *(Micro level)* Interview templates *(Macro level)*	The researcher created templates for interviewing TEL researchers for capturing TEL projects aspects, resulting in a dedicated meta data template. Developed writing explanations and guidance for projects' participants in order to support them to fulfil the Projects Aspects template. Designed the TEL adopters and TEL providers' questionnaires. Validation of templates was done by the Observatory network Input for the development of the electronic portfolios at Confolio
Commencement of Horizon Scanning, Reviewing and analysis of TEL innovations and weak signals 1/09/2011	Researcher Observatory Network IT experts TEL vendors	Reports; mash-ups; social networks; Digital and People sources; Cartography maps; Social Networking	Reviewed and reported on TEL roadmaps, and Future scenarios in Europe and America (Observatory report on Scenarios and TEL futures 30/4/2012) Managed and coordinated the Observatory activities in reviewing the existing State-of-

Follow up milestones: Media Base report Digital resources 30-09-2011 providers/Users survey report 13/2/2012 Report on Scenarios and TEL futures 30/4/2012 Report on Socio-economic developments 9/4/2012 FP7 Projects analysis report 19/06/2012 Advances in Future TEL Scenarios 6/11/ 2012 Report on socio-economic trends and emerging new Learning paradigms (V1) 07/12/2012 update V2) 30/3/2013	TEL providers TEL users TEL stakeholders	Analysis reports and maps; Conzilla maps; Delphi Survey, Interviews; Classification and presentation at the Portal *(Macro level)* Interview with TEL providers/ TEL users Reports *(micro – level)*	the-Art in current EU projects/initiatives and in industry and other communities, as well as in the rest of the world. Assisted Observatory in Delphi study. Supported, capacity building, engagement, alignment of TEL communities, input for the co-innovation group development. Assisted and coordinated the Observatory Network in identifying, classify, data sources (e.g. blogs, TEL foresight links, Conferences, Trade Events, etc.) for Technology Review, Weak signals, and Social Networking Analysis ongoing services.
7th JTEL summer school, Chania, Crete 30/5/ -3/6/ 2011 ***8th JTEL Summer*** School 2012, Estoril, Portugal, 21/5/2012-25/5/2012	PhD Students TEL experts TEL researchers Modellers Researcher	Survey, Interviews, Workshop, Profile metadata vocabularies *(Micro level)* A Network of 20 PhD students joined the Observatory function as modellers and Scouts in TEL Cartography of TEL *(Macro level)*	Development and analysis of survey for students' research. Conducted interviews with students and modelled results. Submitted workshop proposal to JTEL, organised and managed the workshop with PhD students and TEL experts. Co-modelled the results (together with another person). The results were used as input for development of Profile metadata vocabularies in Confolio tool by Observatory developers. Engagement of TEL stakeholders in Co-Innovation Group & Observatory Network
Co-Innovation Workshop 1: shared perspectives Changing schools and creating classrooms, Bologna 10/5/2012	Researcher Roadmap facilitation team Co-Innovation participants	Workshop; (Future Search Event); Report; Shared Google document; Templates; CmapTools conceptual maps; TEL futures;	The researcher provided workshop format, agenda, methodology, and templates. Co-organised the work (with the roadmap core team) at the shared google document of the Co-Innovation group. Managed and coordinated the work with the Roadmapping facilitation team (Future

		TEL forces; Individual perspectives *(micro level)* Shared Desired futures *(meso level)*	Search Facilitators) Analysed results and produced reports Facilitated the collaboration activities prior and after the event with the co-innovation group and Roadmap facilitators Communicated the results to the Observatory group and scheduled follow up activities.
Observatory Workshop 2: Context Scenarios Oslo Norway 4/10/2012	Researcher Observatory Network TEL experts; Researchers; IT experts	Workshop; Reports; Forces, trends, tensions; Four field Scenarios models; *(macro level)*	Organised the workshop, provided the methodology, templates, and agenda. Co-developed context scenarios. Follow up with the co-innovation group.
Co-Innovation Workshop 3: Industry Perspectives Industry group workshop, 'Voicing the TEL Future' 19/9/2012	Researcher; Roadmap facilitation team; TEL vendors; TEL providers; IT providers; Publishers;	Workshop (learning café format); Reports; Shared google document; Templates; *(*Value propositions, market relevance of co-innovation's desired futures to industry: *(micro organisational level),* Industry Recommendations to Co-Innovation Group*: meso level,* Technology review and gap analysis*: macro level)*	The researcher submitted workshop proposal to EC-TEL conference; Provided workshop format, agenda; Presentations, methodology, and templates; Co-organised the work (with the roadmap core team) at the shared google document of the industry participants; Managed and coordinated the work with the Observatory; Analysed results and produced reports Facilitated the collaboration activities prior and after the event with the industry participants; Communicated the results to the Observatory group and scheduled follow up activities.
SWOT analysis of Co-innovation visions in terms of Technology review and recommendations 30/9/2012	Researcher Observatory Network	Report; Recommendations; Presentation of results at the portal; (SWOT analysis: *(macro level)* Recommendations to Co-Innovation group: *(Meso level*)	The researcher provided the SWOT methodology and coordinated the Observatory work.
Co-Innovation Workshop 4: Initial Roadmaps Berlin on 27th November 2012	Researcher; Roadmap facilitating group; Co-innovation group; Observatory Gate Keepers	Roadmapping workshop Reports; Shared Google document; Templates; Large paper	The researcher provided workshop format, agenda, methodology, and templates; Designs; presentations; Co-organised the work (with the roadmap core team) at the shared google document of the Co-Innovation group; Managed and coordinated the work with the

		boards; Pictures of draft roadmaps; CmapTools Roadmap context maps; Excel table; *(meso level)* Individual members' activities *(micro level)* Policy activities *(Macro level)*	Roadmapping facilitation team; Analysed results and produced reports; Facilitated the collaboration activities prior and after the event with the co-innovation group and Roadmap facilitators; Communicated the results to the Observatory group and scheduled follow up activities.
Gap analysis of Co-innovation roadmaps and recommendations Potential for the emerging technologies 15/1/2013 Recommendations of actions grouped in short and medium intervals 28/2/2013	Researcher Observatory Networks	Gap Analysis report (Analysis of the emerging learning technologies) *(macro level); Secondary data & primary data* Gap Analysis between the emerged learning technologies and those technologies envisioned to realize the desired future scenarios & Recommendations to Co-Innovation Group *(meso level)* *Primary data*	The researcher provided the Gap analysis methodology and coordinated the Observatory work. Organised follow up activities (online meetings among the Observatory and the Co-innovation group.)
Co-Innovation Workshop 5: Stress-testing initial roadmaps European Forum on Learning Futures and Innovation, Brussels, Committee of Regions 18-19/3/ 2013	Researcher Roadmap facilitation team Observatory Co-Innovation group Policy Makers TEL users	Reports; Google document; Templates; Paper boards; Cartography model; Value blueprint models; Revised scenarios models; Pictures of draft value prints; CmapTools context maps; Excel table; *(meso level)*	The researcher provided workshop format, agenda, methodology, and templates; Designs; presentations; Co-organised the work (with the roadmap core team) at the shared google document of the Co-Innovation group; Managed and coordinated the work with the with the Observatory; Analysed results and produced reports; Facilitated the collaboration activities prior and after the event with the co-innovation group and Roadmap facilitators; Communicated the results to the Observatory group and scheduled follow up activities.
Technology Assessment and Market relevance of Co-Innovation Roadmaps and	Researcher Observatory	Report Recommendations directly at Co-Innovation roadmaps	The researcher provided the Technology Review methodology and coordinated the Observatory work. Organised follow up activities (online

recommendations Innovations blueprints updates and recommendations 30/4/2013		Recommendations of actions grouped in short and medium intervals for industry participants at filling the technology gaps, taking into account the market potential Technology Review analysis *(macro level)* Market relevance & recommendations *(meso level)*	meetings among the Observatory and the Co-innovation group.) Facilitated the online modelling meetings with the Co-innovation group to revise their Roadmaps Context maps.
Open Education 2030: Exploiting the Potential of OER for School Education, - A Foresight Workshop -Seville, 28-29/5/ 2013	Researcher IPTS unit TEL experts, publishers, researchers, users, TEL industry	Report; Experts Analysis (TEL desired Futures) *(Macro level)* Validation for Co-innovation futures and roadmaps (meso-level)	The researcher was invited by IPTS as a TEL Roadmapping Expert. Participation at the workshop and communication of the co-innovation roadmaps and desired futures. Follow up reports and liaison with the workshop organisers. Liaison and feedback to the co-innovation group.
Updated Roadmaps and value blueprints 15/5/2013	Researcher Observatory network Co-Innovation group	Updated Roadmap Context Maps (CmapTools) Observatory Reports Shared Google Documents Online skype meeting Co-Innovation Roadmaps (meso level); Individual Members actions (micro level) Policy Actions (macro level)	Facilitated and Coordinated the scheduling of Online collaborative meetings with Co-Innovation group, the roadmap facilitation team, and the Observatory network. Observation and writing of reports.
Context Maps TEL roadmaps V2 29-04-2013	Researcher + 1 Modeller	Conzilla Context maps	Modelling (team of two people) of the co-innovation updated Roadmaps at Conzilla browser; Liaison with the co-innovation group; Dissemination of the updated Roadmaps at the Portal. Liaison with Observatory Network.

Table 12: milestones for developing and applying the Dynamic Roadmapping process

Chapter 5: Secondary data analysis: roadmaps evolution in EU TEL projects

Chapter 5 provides an overview of field work in roadmapping in EU TEL projects as a set of different practices in order to a) consider the empirical field in terms of practices and b) identify relevant similarities c) demonstrate how these practices contributed to the further development of the roadmapping concept and practice. It demonstrates how each project was building on the methodologies and work of previous initiatives, and thus, how the Roadmapping practice and process has evolved in the TEL sector. It provides a mapping of these initiatives in terms of methodologies used and the interrelationships between these Roadmapping initiatives. These cases show a continual development of concepts and strategies towards Dynamic Roadmapping in an empirical way.

PROLEARN project was first to recognised roadmapping as a knowledge creation process and to use of SECI framework for knowledge creation; ICOPER used activity theory and disagreement management to schedule the discussions between the roadmapping actors; TEL-Map project used an integrated roadmapping framework and an Observatory function for developing meso level roadmaps. The evolution of roadmapping practice in the TEL roadmaps (time2learn, Prolearn, ICOPER), demonstrated the gaps in the area and the need for a more holistic framework that would integrate foresight, roadmapping and change management methodologies. Each roadmap project was a step forward for the creation of the Meso level co-innovation 'Dynamic Roadmapping' framework and guided the author's initial set of research questions. These research questions were validated via literature review, which led in the development of the final 'Dynamic Roadmapping' framework. This framework was applied in TEL-Map project and presented in this thesis as a case study.

The following initiatives were included for review. These initiatives were managed by the author, who was also responsible for providing the methodological and theoretical framework for the roadmapping participants.

1. *BRIDGES*[16] (industry roadmap - macro level. Digital business sector. The author did not take part in this project.
2. *Time2Learn*[17] (industry roadmap – macro level). TEL sector: professional learning, shorten the time to performance. The author was co-developed the Roadmapping methodology, scenario process, and managed the current state of the art assessment activities.

[16] BRIDGES, a European Commission IST project (IST-1999-14038) http://cordis.europa.eu/project/rcn/57136_en.html

[17] Time2Learn, a European Commission IST project (IST-2001-38263) ftp://ftp.cordis.europa.eu/pub/ist/docs/ka3/eat/TIME2LEARN.pdf

3. *PROLEARN*[18] (research & technology roadmap – macro level). TEL sector: professional learning. The author developed the Roadmapping methodology and process and managed the roadmapping process.

4. *ICOPER*[19] (research and standardisation roadmap – macro level). TEL sector: Outcome based education, emphasis on Higher Education Institutions. The author developed the Roadmapping methodology and process and managed the roadmapping process.

5. *TEL-Map*[20] (multi-organizational meso level roadmap). This project served as a case study for implementing the 'Dynamic Roadmapping' framework, and it is analysed in detail in this thesis. The author developed the roadmapping methodology and managed the roadmapping process.

In addition to roadmapping, the following foresight initiatives are reviewed. The author participated in various workshops, and surveys organised by these initiatives, but she was not involved in the development of the methodologies for these projects.

The following initiatives are included:

1. L-CHANGE[21] (foresight study, market analysis and observatory function).

2. LEONIE[22] (policy foresight). TEL sector: Life Long Learning. The author took part in some of the experts' consultation workshops, and in the weak signals study.

3. LEARNOVATION[23] (2007-2009, and 2010) & LEARNOVATION – CREATE (2010) (Policy Roadmaps). TEL sectors: Lifelong learning, schools, HEIs, work place and informal learning

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[18] PROLEARN Network of Excellence, a European Commission Project (IST-507310) http://prolearn.archiv.zsi.at/

[19] ICOPER best Practice Network, a European Commission eContent+ (ECP 2007 EDU 417007) http://nm.wu.ac.at/nm/icoper

[20] TEL-Map, a European Commission Seventh Framework project (IST-257822) www.learningfrontiers.eu

[21] L-CHANGE - European Observatory on IST related Change in Learning Systems, a European Commission IST project (IST-2000-26226) ftp://ftp.cordis.europa.eu/pub/ist/docs/ka3/eat/L-CHANGE.pdf

[22] LEONIE: Observatory on National and International Evolution, a European Commission SOCRATES programme project http://www.menon.org/projects/learning-in-europe/

[23] Learnovation, a European Commission D.G. Education and Culture project (2007-3612/001-001) http://www.menon.org/projects/fostering-learning-innovation-and-ict-use-in-europe/

4. VISIR[24] project (policy foresight). TEL sector: Life Long Learning. The author took part the experts' consultation workshops.

5.1 Review of Roadmapping Projects

5.1.1 BRIDGES project IST-1999-14038, (Roadmap 2002)

The objective of the BRIDGES project was to prepare a strategic roadmap for digital business. Although not related to learning or TEL, it is presented here for historical reasons: its Roadmapping approach was very influential for most of the Roadmapping projects that followed. It was one of the very first EU projects that produced a roadmap. The project has developed a generic Roadmap model called BRIDGES ROADMAPPER which similarly to time2learn project used an exploratory approach to define the future state. BRIDGES viewed Technology Roadmapping as a "needs-driven" technology planning process to help identify, select and develop technology alternatives to satisfy a set of product needs. Similarly to Time2Learn it based its methodology on the IMTI approach but took a more strategic view. Bridges developed the ROADMAPPER model, as generic methodology for building roadmaps (see Figure 74):

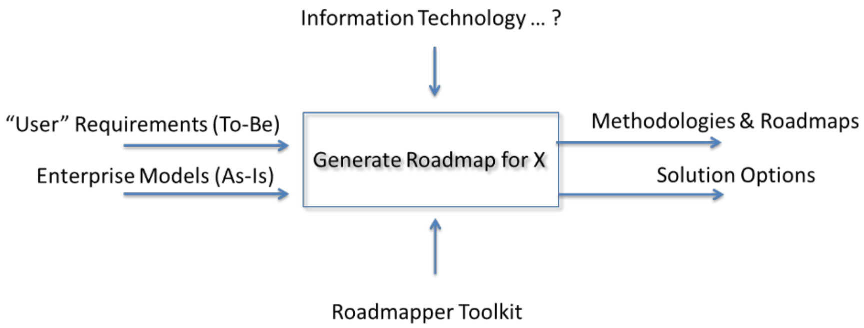


Figure 74: Functional Model of Roadmapper. Adapted from (CIMRU 2002) *project from figure 8, p.106*

It contains the following elements:

- AS-IS analysis
- TO-BE analysis
- SWOT analysis
- EU-US similarities/differences
- Relevant information and projects

[24] VISIR, a European Commission Life Long learning Project, http://visir-network.eu/

A market analysis and a conceptual model of the digital business domain were also produced. They also built an interesting approach to perform Gap Analysis between the state of the art and the scenarios using a SWOT methodology (see Figure 75).

Internal elements / External elements	Have & Want (Strengths)	Have & Not Want (Weaknesses)
Not Have & Want (Opportunities)	SO: Strengths can be used to capitalize or build upon existing or emerging opportunities	WO: The options developed need to overcome weaknesses if existing or emerging opportunities are to be exploited
Not Have & Not Want (Threats)	ST: : Strengths can be used to minimize existing or emerging threats	WT: The options pursued must minimise or overcome weaknesses and as far as possible, cope with threats

Figure 75: Mapping Strengths & Weaknesses to External Opportunities & Threats. Figure adapted from (CIMRU 2002) *project, from figure 10, p.105*

During this phase, SWOT analysis was used to identify the strengths, weaknesses, opportunities and competence-related threats to realize each future scenario. This analysis provided us with the distinct competencies that we have today (Strengths) and the key capabilities (opportunities) that we need in the future in order to realize the Roadmap scenarios. In addition, the negative or problematic factors (weaknesses, and threats) that hinder the realization of the scenarios were identified. The problem with such an approach to GAP analysis is that it doesn't differentiate between internal (micro) and external (macro) threats. Although, a classification of micro and macro drivers was attempted prior to SWOT analysis, the impact of the macro trends was not clearly documented. External threats, which produce tensions that can have either positive or negative impact on the future planning, usually have related trends and weak signals, enabling them to be monitored so that relevant alerts can be produced.

Key Results: Roadmapping methodology, PESTLE & SWOT analysis, trends, challenges-recommendations.

5.1.2 Time2Learn project, IST-2001-38263, (Roadmap 2004)

TIME2LEARN project developed a roadmap for ICT-enabled European professional and vocational training. The aim was to demonstrate how to reduce the 'time to performance' of workers and professionals, in order to enable them to be more effective, adaptable and employable. Time to performance is now a widely-used metric in TEL-based vocational training, so this project is very relevant to TEL practice. It represented the period of time that elapses from the initial creation of the knowledge to the ability to apply that knowledge in a particular situation by a particular learner. It encompassed the entire learning and training value-chain from content creation to production and delivery of the ICT-enhanced training service and learner support. The goal of the project was to shorten the time needed to:

- identify knowledge gaps
- identify existing learning/training offers or potential providers for the needed educational scenario
- produce/adapt the needed learning processes
- deliver the needed training
- assess the needed training

The Time2Learn project adopted a Roadmapping methodology developed by the US Integrated Manufacturing Technology Initiative (IMTI). IMTI[25] Roadmaps was an industry/government partnership facilitating collaborative development of critical manufacturing technologies. The time2Learn model consists of six levels in a top-down pyramidal structure (Figure 76).

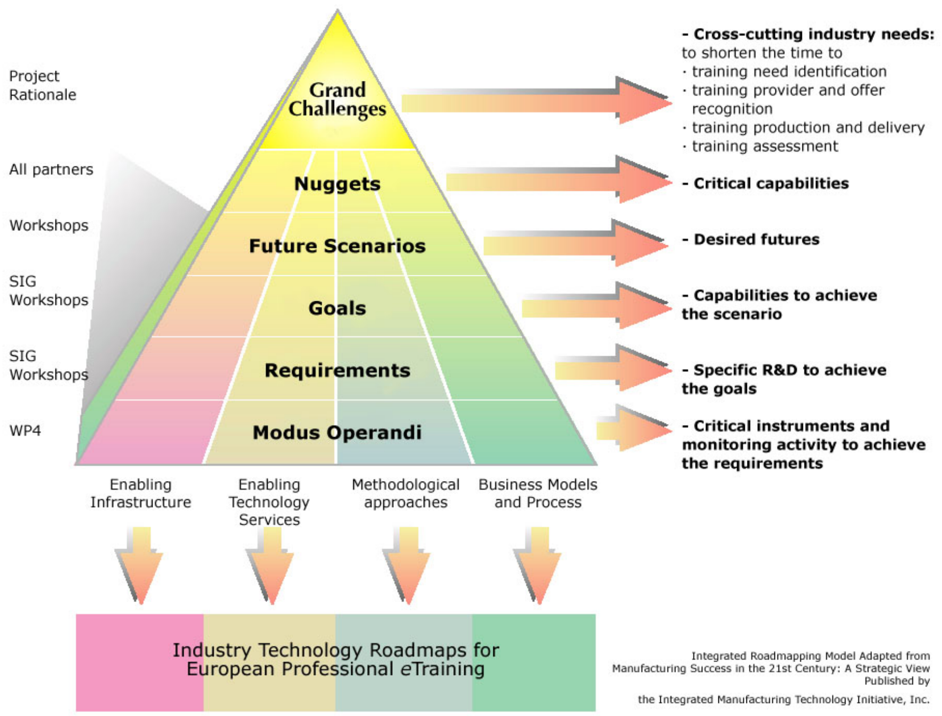


Figure 76: Time2Learn roadmapping framework, based on IMTI 6-Level Model for Industry Roadmapping, Adopted from (TIME2LEARN 2003) *figure 1, P.9*

This methodology provided a detailed **top-down process** consisting of several steps starting from a) defining the big picture in Professional training (Grand challenges, nuggets

[25] IMTI: Integrated Manufacturing Technology Initiative. IMTI was a US industry/government partnership, which facilitated collaborative development of critical manufacturing technologies.

comprising the grand challenges, and critical capabilities to achieve these challenges); b) developing scenarios describing alternative futures; c) and performing a gap analysis based on an assessment of the state of the art in terms of the maturity levels of technology to achieve the critical capabilities identified in the scenarios and in the big picture. The process in this approach was guided by providing answers to the following questions: How can we use learning to shorten the time to performance? What challenges will we face in the future? What capabilities will we need to meet these challenges? How can these solutions be developed? How can we shape and speed the outcome? In addition, a set of 4 scenarios were developed. 'The aim of scenario planning was to describe what professional eTraining might be like for ordinary people in 2010'. In order to draw the roadmap between the current situation and the desired future states, the future scenarios were analysed and studied. This approach was used in order to rank the Nuggets (and identify the most important critical capabilities), get an indication of the key future developments in infrastructures, technologies, methodologies and compare them to the identified current state. Figure 77 below depicts the gap analysis process used in Time2Learn.

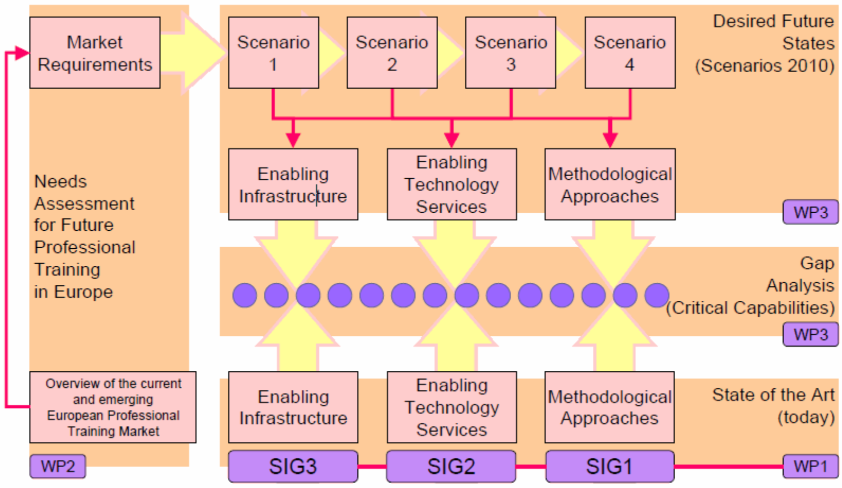


Figure 77. Gap Analysis of Both Required & Current Enabling Infrastructures, Technologies & Methods. Figure adopted from (TIME2LEARN 2003) *from figure 2, p.11*

Key Results: Roadmapping methodology, Grand challenge, nuggets comprising the Grand challenge, State of the art assessment (methods, tools, infrastructure), Market analysis and future needs assessment, context/domain scenarios, gaps, critical capabilities, R&D priorities and threats & challenges. The scenario approach used in Time2learn was based on an explorative approach based on a 2 by 2 matrix that outlined 4 different scenarios. This kind of approach may limit the innovative and creative aspects of Roadmapping by focusing on the current state of developments and current needs via a very small number (4) of scenarios based mainly on microscopic views. Time2learn, although recognized that the importance of the value of Roadmapping lies "largely behind its capabilities to enhance consensus building", the method that was used was based on an expert top-down approach, which started from a predefined set of grand challenges that drive the creative process of the foresight activities. This kind of top-down approach doesn't support the aim of Roadmapping as a process that enables the community, who builds the roadmap to bring up its visions for the “desired futures”. We can rather assume that a predefined set of grand-challenges would limit the by-in of the industry stakeholders and their desire to implement the roadmap’s recommendations. A wider participation of the stakeholders and main industry players in the roadmapping process is therefore necessary. In addition, being macro level roadmaps, both BRIDGES and Time2Learn did not provide any plan for operationalization of the roadmapping actions.

5.1.3 The PROLEARN Project: IST-507310, (Roadmap 2008)

Methodology and process

PROLEARN project developed its own Roadmapping methodology, based on Time2Learn and a number of other projects such as IMS and IMTI. Recognising Roadmapping as a forward chain activity “invent our future first and then find the current that lead us there” PROLEARN has adopted ***a normative proactive approach*** in developing its roadmap for Professional Learning. Following this principle, the starting point was to invent the future first and to “plan backwards” from there in order to link up with today.

PROLEARN employs the following instruments in its Roadmapping methodology:

- A modified version of SECI framework for Knowledge Creation (Roadmapping as a knowledge creation process).
- Foresight activities such as Trend-analysis, surveys, interviews, user requirements analysis, expert workshops and symposiums (learning cafes), literature review, state of the art assessment, scenario development, SWOT analysis and modelling.
- Conceptual modelling using semantic modelling tools for capturing and extending the knowledge and positions of different communities.

PROLEARN roadmapping process is depicted in Figure 79 below:

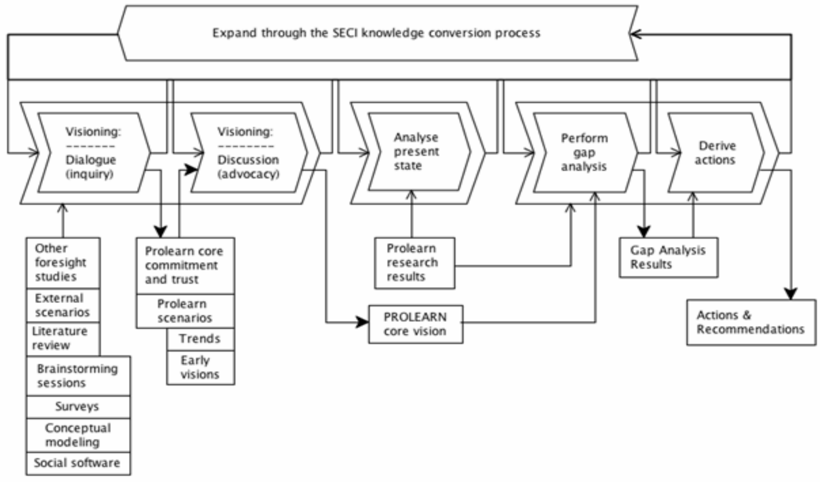


Figure 79: PROLEARN Roadmapping process, from (Kamtsiou et al. 2008) *from figure 2, p.4*

SECI Framework for Knowledge Creation – Roadmapping as a knowledge creation process

PROLEARN added another component to its methodology: The application of the SECI spiral of Knowledge creation framework (Nonaka & Toyama 2003), (Nonaka & Takeuchi 1995a), (Nonaka et al. 2000) in order to a) develop a value accumulating Roadmapping process, which is dynamic and has high potential for sustainability and b) promote a knowledge network of Roadmapping that amplifies the efforts of various groups and crystallizes them at the European level, influencing a large part of the EU TEL community.

In PROLEARN, Roadmapping is a knowledge creating process that spirals outwards from the core partners of the PROLEARN Network (individuals, groups, the whole Network) via the Network's associated partners, to the entire scientific community and industry. Therefore, it is both a learning activity and a knowledge creation process for the community that builds the roadmap. This knowledge creation process has been modelled using the general SECI process framework (see Figure 80), known as the "SECI Spiral" (Kamtsiou et al. 2005), (Naeve et al. 2006), (Kamtsiou et al. 2006).

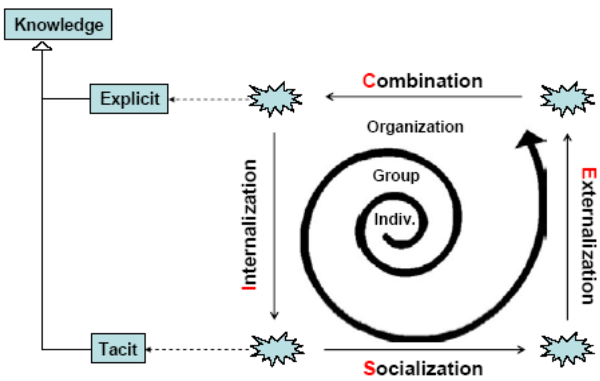


Figure 80: SECI Knowledge Creation Spiral. Figure adapted from (Naeve et al. 2005) from figure 10, p.12

According to Nonaka (2003, 2000, 1995) the key to knowledge creation lies in the following four SECI modes of knowledge conversion, which occur when tacit knowledge and explicit knowledge interact with each other: socialization, externalization, combination, internalization. Because tacit knowledge includes mental models and beliefs in addition to know-how, moving from tacit to the explicit is really a process of articulating one's vision of the world – what it is and what it ought to be (Nonaka & Toyama 2003), (Nonaka & Takeuchi 1995a), (Nonaka et al. 2000).

PROLEARN Roadmapping process framework was derived from the general SECI process framework by replacing the triplet of social entities {Individual, Group, and Organization} with {Core Partners, Associate Partners, and Scientific Community & Industry}.

During the *Socialization process*, networking activities and community building tools are important. Face to face meetings, various workshops, and virtual meetings have been organized in order to bring together the wider community of the PROLEARN network on a common contextual platform and tap into their collective experience and knowledge. PROLEARN teams played a central role in this knowledge creation process of building the roadmap because they provided the shared context where the team members interacted with each other and engage themselves in common projects and activities on which effective reflection depends. This provides a new individual understanding of the relevant concepts and their relationship.

During the *Externalization process*, this new "know-how" is articulated and expressed via a constant dialogue where teams pool their information and examine it from different angles, thus integrating their diverse individual perspectives into a new collective perspective.

During the *Combination process*, the resulting "seed" knowledge is modelled and conceptualized and thus is easily communicated to external groups in order to synthesize information from many different sources and bring in different perspectives and contexts. In that way, an increased collective understanding is achieved where the actual concepts and their contexts are reinvented and extended by others. The principle is to find what we agree on, what we disagree on and presenting it in a way that we all agree on (Naeve et al., 2005; Naeve, 2009).

During *Internalization process*, the manifestos and the results of gap analysis were further analysed and a portfolio of short term, midterm and long term actions and recommendations were produced. This explicit knowledge, in turn, can be reflected upon and internalized into new tacit knowledge, completing a full turn of the SECI spiral. Reflective analysis tools were used during this stage.

The PROLEARN roadmap was focused primarily **on the desired future.** The roadmap was built in terms of its purpose focus, bringing out the visions and purposes of the TEL community. In the years since PROLEARN, its methodology has spread to other TEL projects (e.g., ICOPER, STELLAR, TEL-Map) and its results were taken up by research and development projects such as TEN-COMPETENCE, PROLIX, ROLE, ODS).

Key Results: visions, goals, factors, assumptions, preconditions, gaps, and recommendations.

This enhancement of the mainstream roadmapping framework is an especially important improvement for TEL, since the roadmap is a commonly agreed and accepted vision, and not a mechanically derived result. PROLEARN extended the Roadmapping activity to go beyond strategic planning (time2learn), to be dealt as a knowledge creation process specialised for TEL, where the importance of disagreement management through discourse is emphasized. In addition, it added conceptual modelling as a core of the Roadmapping activities in order to facilitate the stages of convergence and synthesis of the new knowledge and transcend individual understandings in increased shared understandings.

The resources available during PROLEARN did not allow for investing effort in developing methodologies to identify threats that could challenge these visions and risk the implementation of the desired future. At the same time, although the SECI model used did provide an understanding of how do we go from representation of Knowledge to the dynamic knowledge creation, and what is involved in this transmission, it did not provide any means for the management of the Knowledge creation. SECI tells us what are the types of knowledge conversion that could apply in knowledge creation and how they appear. In that sense, a complementary mechanism is needed in order to better determine the relevance of the strategic issues identified, the seed input chosen as a starting point for discourse, and the management of knowledge creation in terms of increasing the motivation of communities to participate as well as manage effectively any conflicting interests of these communities.

5.1.4 The ICOPER best Practice Network: ECP 2007 EDU 417007 (Roadmap 2011)

The ICOPER Best Practice Network developed a technology roadmap and a reference model (IRM) for standards development in the domain of Learning, Education and Training. ICOPER raised issues of how to improve requirement gathering when designing solutions for an unmapped territory as competency-driven learning and teaching. Through Roadmapping activities ICOPER worked on models describing how community requirements are fed into the specification design process and valorised in the standards consensus process. The project provided methodologies of how to utilize conceptual modelling techniques that are publicly available in order to enable different groups to map emerging trends, opportunities and threats and provide a European insights tapping system for their communities and stakeholders. The ICOPER Roadmapping methodology made extensive use of foresight analysis methods, including "visioning" (scenario development), "futuring" (force-field analysis - weak signals analysis), and "gap analysis" (gaps identification, SWOT, gaps assessment and recommendations). In addition, modeling tools (CmapTools) were used for capturing and extending the knowledge and modeling activities of the targeted group communities. The results of these models were compared and contrasted in order to map out the differences and similarities among them and in this way, enable disagreement management among the positions of the different groups (Kamtsiou & Klobučar 2013).

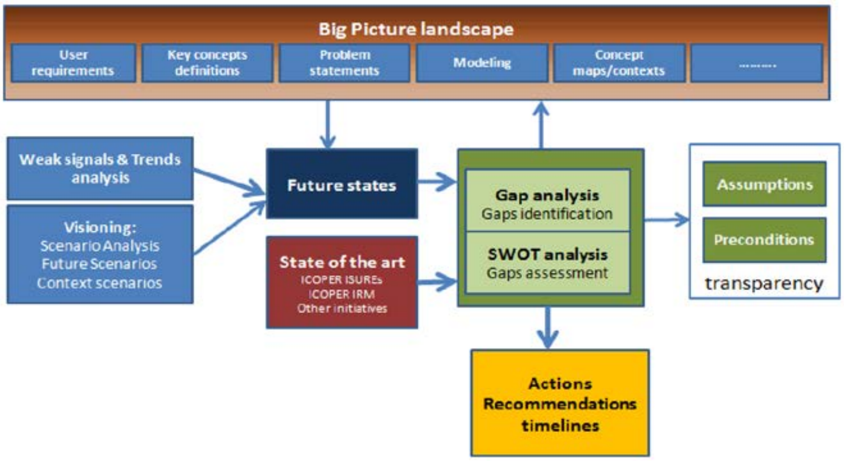


Figure 81. ICOPER Roadmapping components. Adapted from (Kamtsiou & Klobučar 2013) *from figure 5, p2241*

ICOPER raised the issues of how to improve requirement gathering when designing solutions for an unmapped territory such as the competency-driven learning and teaching. It had advocated a ***bottom-up approach*** with a number of mechanisms to ensure the involvement and cooperation of the relevant stakeholders. This is a good example, where the Roadmapping activities were followed by different stakeholders working under an umbrella organisation of special interesting group in the area. In order to solve the problem with SECI management, ICOPER has introduced the use of the ***Activity theory (CHAT)*** **(**Engeström, 2001) as the theoretical framework to support the interactions among the ICOPER and the different networks, which are linked by specific shared issues/problems they are trying to investigate/solve and through the scheduling of common activities (Kamtsiou & Klobučar 2013). The aim was to support and strengthen networks of people that are connected by shared objects (what they investigate, produce, e.g. learning technology specifications, tools, applications, best practices, training, etc.) through activities. The main concern was with the relationships between people and issues, with a special focus on the shared objects of the particular networks and the rules and practices that the different activity systems are built up. In addition, ICOPER demonstrated the ***use of disagreement management approaches*** via conceptual modelling which led to new standardisation proposals (for example the InLOC proposal to CEN and PALO specification) (Kamtsiou & Klobučar 2013). This is a good example, where the Roadmapping activities were followed by different groups under an umbrella special interesting group in the area.

Key Results: desired scenarios, context/domain scenarios, trends, weak-signals, gaps, recommendations, assumptions, top-level harmonised conceptual model. The following Figures set out the main driving and restraining forces impacting on key themes. They can be used a basis for identifying trends and weak-signals to be watched for.

I COPER was very successful in providing the domain scenarios, process and service analysis that have governed the development of the ICOPER Reference model (short term Roadmapping recommendations & actions), but was not equally successful in providing dynamic monitoring for the mid and longer term recommendations. Although the ICOPER roadmapping SIG included stakeholders from the academia, standardisation bodies and policy makers, there was a limited participation of real user communities of competency development models, besides university teachers and curricula developers. For the implementation of the long term recommendations, and the monitoring and continuation of this work, it is important for the developers of the competency models to provide evidence of the application and fit of their models in real life, with the actual adopters of their models, whether they are providers or users of competency based education and provide any concrete examples or at least set of requirements that have based their models on. At the same time, the roadmapping SIG needs to find domain-specific cases against which these models can be tested for adoption and fit. This will lead to a better understanding of how the perceived value and impact of the offerings will be measured against how the user community understands rates and understand them. Ideally, according to the ICOPER Roadmapping philosophy, it should be the model trying to adopt/fit the users' specific requirements and not the other way around. A bottom up perspective and process for creating standards and specifications using concrete situations, where the actual user needs are taken into account would strongly support the adoption of standards. The European Competency SIG is one of the instruments created for this purpose. Otherwise, any standard will remain an academic exercise of pre-conceived theoretical notions of what a competence should be.

Prolearn and ICOPER, although both enhanced the roadmapping approach as a knowledge creation process, they did not provide any mechanism to keep the process dynamically updated. This raises several issues such as: How to provide a better horizon scan and analysis of factors of change that might affect the relevance and efficiency of the identified visions in relation to the emerging reality? How to estimate the impact of each issue on the future visions (identification of the impact as a threat or opportunity or both)? How can we provide a dynamic process for modelling the policy, economic, social and other factors that help and hinder the adoption of the visions and other developments spotted by this alert system? How such assumptions on future developments affect the gap assessment during the gap analysis?

5.1.5 TEL-Map Roadmap: IST-257822 (Roadmap 2013)

TEL-Map project built in the approach of PROLEARN and ICOPER roadmaps in order to develop a ***third generation, meso-level, multi-stakeholder roadmapping***, which has evolved from and complements of micro- or company-level roadmapping and macro- or sector-level roadmapping/foresight approaches. It has been developed to meet the needs of increasingly complex systemic innovations, where multiple co-innovators and 'customers' involve multiple decision makers and need to be included in the development process as co-innovators. In this approach, the participating organisations identify a common desired future, derive and test their own roadmap for themselves to implement. It sets out a new 'dynamic', 'adaptive' or 'agile' approach to innovation management, designed to enable multiple co-innovators strategically plan and coordinate their efforts to bring systemic innovations through to the point of adoption and mainstreaming, despite a turbulent operating environment. This approach ***integrates foresight, roadmapping and change management methodologies at a meso, multi-organizational, level.*** It is suitable for complex domains such as in the field of Technology Enhanced Learning (TEL), which is a diverse and multilevel domain, involving many types of players, working in different cultures, under varying jurisdictions, with differing and sometimes opposite approaches to pedagogy and the task of education (Kamtsiou & Olivier 2012), (Kamtsiou 2013).

TEL-Map also used weak signal methodologies to develop a framework that takes into account observations (issues, factors, conflicts, weak signals, trends) about how recent changes may affect the Roadmapping outputs (e.g. visions, gaps, recommendations) based on an investigation on the key uncertainties and their impact as they are perceived today. In this case and specifically building on the weak signal and trends analysis approach, a number of context scenarios are devised in order to get an indication about the Probability, Feasibility, Desirability and importance of future events and what this would mean for the Roadmapping desired scenarios. The aim of this approach is to analyse a possible impact of these events in the roadmap visions and meaningfully revise the roadmaps. This emerging constructed picture will provide a new unit of analysis as new input to drive another cycle of discourse and further assess and develop the Roadmapping outputs as they are progressing in timelines. This method is also a good approach to complement the future scenarios in terms of avoiding wishful thinking mentalities and dismissing of scenarios that are probable but not perceived as desirable.

Along with dynamically stress-testing the roadmaps against the emerging realities of the context scenarios, TEL-Map project also adopted **Adner's model** (Adner 2012) for managing their successful implementation and adoption. Under this approach, **co-innovation value blueprints** are created for each design solution in the roadmap. Each of the actors who create and add value for the implementation of the design solution is identified in a value blueprint. Their willingness to participate is simplified and represented in the map as a green, yellow or red traffic light against each player, indicating respectively a) whether a key co-innovator will benefit from the innovation and is ready to go; b) will not benefit or lose and so in an uncertain state; c) will lose out from the innovation and is therefore unwilling to participate. Another major contribution to Roadmapping methodologies from TEL-Map was the creation of **an observatory** as a necessary addition for the successful implementation of a roadmap. They argue that in order to keep any developed roadmap dynamic and agile, the roadmap's key drivers, uncertainty dimensions and assumptions need to be fed into an observatory function that supports the roadmapping implementation and update process. It uses these to scan for relevant developments in the wider contexts in which the roadmap is operating, which it feeds back to the roadmapping group. Thus, the roadmapping group should regularly monitor the uncertainties associated with future forecasts, trends and signals identified in its foresight projections by continuously checking these against current realities, so that it can review and update its roadmaps, context scenarios, its targets and even its desired future, as necessary.

Key results: co-innovation roadmaps for Higher Education and Schools domains, visions, context scenarios, signals analysis, Gap analysis, and adoption blueprints, TEL observatory.

The TEL-Map project served as the case study in this thesis. The author was the roadmapping manager of the TEL-Map project and developed the 'Dynamic Roadmapping' framework and its theoretical grounding.

Common features

A set of common features were identified based on the investigation of the Roadmapping methodologies of the previously mentioned projects:

- *Timelines:* The scope of the Roadmapping is between 10 and 15 years. The future timeline is divided into 3 segments (present, short, medium and long term).
- All projects have used *scenarios* in order to either define future states (roadmapping initiatives used mainly visionary (normative) scenarios) or to assess future contexts (foresight projects used exploratory future scenarios).
- All projects *performed a current state assessment or a base line* (Where we are today?)
- All projects have performed *Gap Analysis* by comparing the future state with the current state assessment in order to identify the bottlenecks of evolution (What we need that we don't have today?)
- All projects have developed *hierarchical topics* for the phenomena studied. The terminology varies but the core principle remains the same. (Sectors, Scenario components, Vision Statements, Paradigms, Nuggets, Critical capabilities ...)
- All projects have used *some kind of maturity level assessment* (number of maturity levels and their description varies)
- All projects have *used survey- and analysis tools* (e.g. Trends, Weak signals, SWOT, etc.)

5.2 Review of Foresight Projects

5.2.1 L-CHANGE - European Observatory on IST related Change in Learning Systems (2001-2003)

The L-CHANGE project aimed to create an observation system in order to analyse the changes affecting education, training and lifelong learning, due to advances in IST (Information Society Technology) technologies (IST). This work included market, policy, and research and practice analysis.

Key Results: The project produced two main annual reports which analysed the European Education and Training market, and an overview of policies, research, innovative practice and trends in education and training in Europe. Individual country reports were also produced for the following European countries: DE, DK, ES, FR, GR, IT, UK, and for the US.

5.2.2 LEONIE: Observatory on National and International Evolution (2003-2006)

The LEONIE project developed a policy foresight methodology for analysing learning systems evaluation, which was implemented by organisations such as EURYDICE and CEDEFOP. It provided a first approach for the development of a European Observatory function for education and training. Its aim was to provide policy recommendations to Member Countries and European Institutions, and contribute to an open coordination approach in lifelong learning sector in order to assist the achievement of the long term objectives for European education and training. LEONIE project addressed the issue of learning systems evaluation and education and training policy development. The project developed real-life based scenarios of the possible future developments of the learning systems, by focusing on five main domains of change: structure, content, interface, globalisation, and market development. It also studied and assessed the impact of various trends. LEONIE first introduced the concept of weak-signals as a foresight methodology in EU projects. It also utilised Desk research, Selection of indicators, DELPHI survey, and 8 national stakeholders' seminars. The final results were synthesized in a report & final workshop.

Key Results: Core tensions for the future of learning systems, exogenous Drivers of Change in Education & Training, contexts scenarios for Education & Training, recommendations for Policy Actions.

5.2.3 Learnovation (2007-2010)

Methodology and processes – (Policy Roadmap)

Learnovation used policy foresight activity to develop a new vision of TEL in Europe, through a consensus process, which goes beyond the traditional borders of education and training and addresses learning in a much broader perspective**,** focused on its role in innovation and lifelong learning implementation.

Learnovation developed two parallel processes, with feedback loops from one to the other, which provided the basis for the foresight exercise:

- Exploring *emerging innovation paradigms* and the actual and expected role for ICT across the lifelong learning area. Desk/field research activity was used in order to explore the emerging innovation paradigms, map these paradigms in twelve eLearning territories, assess the impact of TEL *on policy discourse and priorities* throughout the 12 territories and build a picture of where we are and where it seems we are going.
- *Consensus building:* Open and result-oriented dialogue was organised through multi-stakeholders seminars, which aimed at discussing and validating the work done and open up new issues feeding the Learnovation results.

The findings of the exploration exercise, combined with the outcomes of the *Learnovation Open Forum* defined the *"Learnovation statements"*, setting more *urgent actions* for change in each territory as well as cross cutting their borders. The Learnovation foresight activity starts from these findings as well as from an autonomous exercise of *scenario planning* - building on literature review, previous relevant projects and internal brainstorming within the Learnovation consortium – aimed at identifying both likely *forthcoming trends and actions to shape the future*, hereby defining on going *drivers of change and domains of transformation,* together with *priority actions* to deal with them.

This methodology followed by Learnovation project is based on experts' seminars and Delphi survey, as well as desk-top research, trends analysis and scenario planning. The methodology seems to rely more to exploratory foresight activities such as trends analysis in order to define drivers of change and future context scenarios (so as to build a picture of where we are and where it seems we are going) rather than a normative approach using desired scenarios in order to define the desired states first and then look backwards to today (e.g. Prolearn roadmap).

DELPHI study: The DELPHI survey used three consecutive rounds of questionnaires, and aimed at collecting experts' opinion and reach consensus *on the expected future* of learning:

- the experts' view on the main factors affecting change of learning systems;
- the experts' opinion on the future evolution of learning systems if no relevant policy is implemented;
- The experts' suggestions for the priority actions to be undertaken in order to reach the desired (rather than the undesirable) scenarios of evolution in the future.

200 experts have been invited to participate in the survey and, among them, 44 have participated in the first round, and a 50% of them completed the DELPHI survey. The first and second round questionnaire was launched in June 2009.

Key Results: Delphi study, future scenarios, policy actions, manifesto.

5.2.4 VISIR (2011- 2014)

VISIR was a policy foresight project that supported the Lifelong Learning Programme of the European Commission in order to analyse three gaps associated with the ICT for learning in Europe: the 'understanding gap', the 'networking gap' and the 'mainstreaming gap'.

Its methodology consisted of three level of analysis, a) macro level (education and training systems), b) meso level (learning organisations) and c) Micro level (teaching and learning opportunities). Its foresight component included several consultation meetings with 'ICT in learning' stakeholders, who helped to draft the VISIR vision report on the contribution of ICT learning in Europe. The initial VISIR vision was further validated via a four board online consultations with stakeholders and 6 face to face seminars. The project also focused on identifying ‘micro-innovation practices’ which deemed to have high impact potential. Micro scale is meant in terms of implementation scope, size of idea-generator, and degree of actual change. For this purpose the project performed a bottom-up cartography, which resulted in the identification and analysis of 120 micro-innovation cases. VISIR and TEL-Map were closely collaborating. They coordinated their foresight activities, and often co-located their events and shared their communities of stakeholders and experts. This has provided an effective integration between foresight and roadmapping activities, and enabled the projects' communities to share and validate the results.

Key Results: Vision for ICT in learning, Gaps, scenarios, Domains of change, cartography of micro-innovations.

5.3 Evolution of Roadmapping and Foresight technologies

A mapping of previous initiatives, in terms of methodologies used and the interrelationships between these methodologies, is produced base on the above analysis (see Figure 82). TEL-Map, ICOPER, PROLEARN, Time2Learn, BRIDGES, IMTI and IMS are Technology Roadmaps, while L-Change, LEONIE, LEARNOVATION and VISIR are foresight and Policy initiatives.

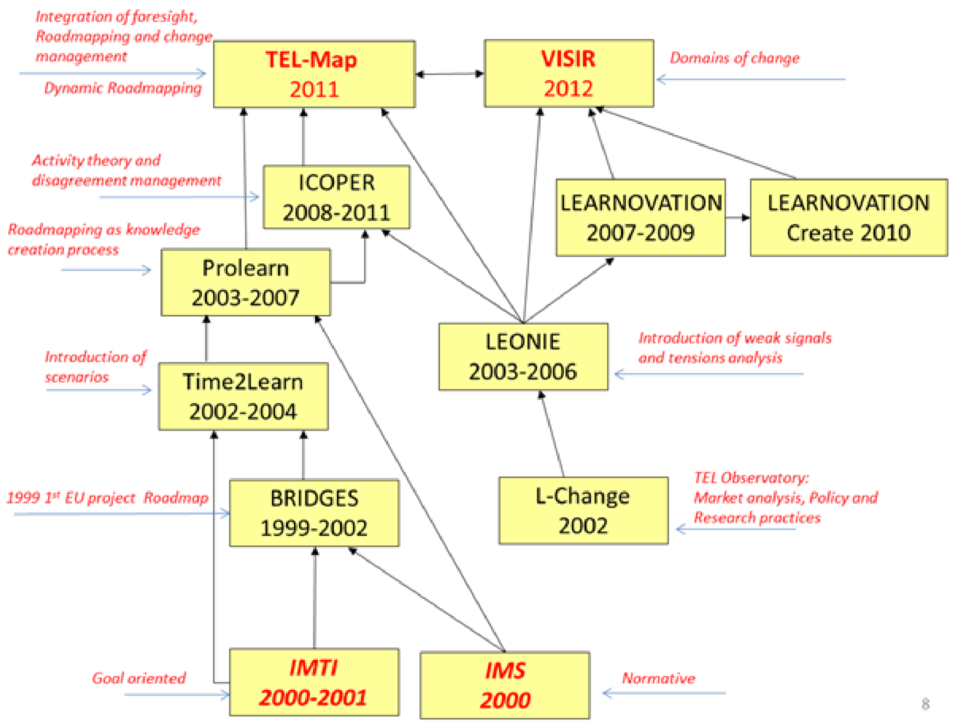


Figure 82: Interrelations of Roadmap Methodologies

The figure above shows the evolution and the interrelationships between these roadmapping and foresight methodologies. All initiatives reviewed, have adapted Roadmapping methodologies developed by earlier initiatives. Already started in 1999, the BRIDGES “Roadmapper” built on the experience from the IMS groups (Intelligent Manufacturing

Systems Expert Group, Technology Map for Manufacturing) and the IMTI. Time2Learn directly build its model on the IMTI Roadmapping methodology, while it also incorporated an extensive market analysis and customers drivers for building its roadmap.

PROLEARN roadmap extended the Time2Learn methodology and introduced a new model based on the SECI framework of Knowledge creation process (Nonaka et al. 2000) (Nonaka & Takeuchi 1995a) (Nonaka & Toyama 2003) combined with conceptual modelling and foresight analysis. In PROLEARN, this approach was used in order to conduct a pan-European foresight exercise on the future of technology-enhanced professional learning and present the emerging and future trends and visions describing the desired future state (Kamtsiou et al. 2006). The study employed a fresh approach to Roadmapping and the task of identifying the prevalent future visions involved a series of consensus-building activities including scenario-building and community-based dialogue, surveys and forums.

ICOPER project has built on the PROLEARN (Kamtsiou et al. 2006) methodology. It incorporated domain scenarios for defining plausible TEL futures, as well as a disagreement management approach in order to reach consensus on a conceptual model for the domain. In addition, the activity theory was used in order to schedule the interactions among the communities and provide the first seed input for discussions based on the communities shared interests (Kamtsiou & Klobučar 2013). TEL-Map introduced the *term 'Dynamic Roadmapping'* (Kamtsiou & Olivier 2012), which further expanded the ICOPER (Kamtsiou & Klobučar 2013) and PROLEARN methodologies . TEL-Map project applied the 'Dynamic Roadmapping' framework in order to extend the Prolearn and ICOPER methodologies, by combining the widely adopted Future Search, scenario planning approaches, and change management together with participatory observatory techniques. The 'Dynamic Roadmapping' methodology developed in TEL-Map project seeks to overcome the limitations of earlier European roadmapping projects where "experts" produced roadmaps that were arguably not followed by others or were rapidly outdated by changing circumstances. In contrast, the TEL-Map approach seeks to support clusters of mutually dependent TEL actors with a shared concern or area of interest, whose participants already have a responsibility for moving it forward and between them have the resources, skills, authority, knowledge and need to bring about innovation. It is considered as a 3rd generation roadmapping methodology, which integrates methodologies from foresight, visioning, Roadmapping and change management.

In parallel, several Policy Roadmapping efforts were developed based on foresight methodologies. L-Change was the first comprehensive market analysis on TEL in different EU countries, and an analysis of policy and research practices. LEONIE project built on the L-Change observatory work for TEL and it additionally introduced weak signals analysis as a foresight method to identify trends and signals that could affect TEL in the future. TEL-Map and ICOPER projects have also used the weak signals approach developed by LEONIE project in their own Roadmapping methodologies. Learnovation project has built on the LEONIE methodology and results and it additionally incorporated a DELPHI study in order to develop context scenarios for different TEL sectors based on a 2x2 matrix. VISIR extended the LEONIE and LEARNOVATION approach by using a bottom up approach to provide cartography for the TEL domain based on actual grassroots innovations. The project identified and described a leading 100 European micro-innovation practices on using information technology for learning in Europe and it will analyse their contribution to transforming education and training systems. TEL-Map and VISIR had a close collaboration in order to gain insights from each project methodologies and results. They have co-organized several events where they shared their networks of experts and stakeholders. Tel-Map having a strong connection to Technology experts, TEL researchers and TEL providers, while VISIR was closer to academic, policy networks such as EDEN, EFQUEL, IPTS, EFMD etc.

One common issue in most of the above initiatives was that once the financing of the future oriented activity ends, there is no way to provide for any kind of follow up to support its broad validation, adoption and take up. The internal motivation for the communities to participate in such process is very important, as well as a process that allows such involvement and their collaboration. On the other hand, since these methodologies have a long term perspective, it is not clear how long it takes for different benefits to become visible. Some manifest early on, while some may require a learning process or even restructuring of related processes, thereby, increasing the time and effort required for the Roadmap to be adopted. One fundamental problem in the early roadmapping initiatives, Bridget, time2learn, Prolearn is that the focus has been on the roadmap as an end “product” and not as a “process” (Roadmapping) which can be more broadly and easily used.

A dynamic iterative process with integrated feedback loops is of critical importance in order to continuously update the roadmap outcomes and answer important questions such as: are any important technology solutions missed? Are any recent developments or factors of change taken into account? Is the scenarios used representative of the future state or need adjustment? Are there other communities who have conflicting scenarios? Are these scenarios desirable? Are there economic, social power structures that will hinder the Roadmapping progress? This dynamic process is especially needed today in areas that undergo rapid and continuous changes, such as technology based areas and which are characterised by systemic innovations. The nature of systemic innovations, demand for stress-testing the roadmaps’ normative scenarios and actions in the context of different plausible futures, which are affected by emerging socio-economic, political, technological, organisational and environmental drivers and situations. For example: How to provide a better horizon scan and analysis of factors of change that might affect the relevance and efficiency of the identified visions in relation to the emerging reality? How to estimate the impact of each issue on the future visions (identification of the impact as a threat or opportunity or both)? How can we provide a dynamic process for modelling the policy, economic, social and other factors that help and hinder the adoption of the visions and other developments spotted by this alert system?

The above analysis led to the Problem Statement: To investigate and theory and practice of building realizable meso level dynamic roadmaps for developing and managing systemic innovations.

The effect impact would be:

- Managing uncertainty in Future planning
- Developing and managing emergent systemic innovations
- Monitoring the produced Roadmaps according to emerging reality
- Support their adoption and take-up after the initial roadmapping process is completed

An integration of Foresight and Roadmapping methodologies was advocated by the TEL-Map project in order to achieve a dynamic systemic approach for dealing with innovations in TEL and manage their operational implementation. In addition, a link to an observatory functions would enable the dynamic monitoring and keeping of the roadmapping process alive. Therefore, we see that literature review and field work are in agreement in relation to research gaps. These gaps stemming from Literature review and field work are summarised and discussed in the following sections 1.4 & 2.5.

Chapter 6: Case study: 'Dynamic Roadmapping' Framework implementation in European schools sector

The Dynamic Roadmapping approach was successfully applied in TEL-Map project[26], a Coordination and Support Action (October 2010 – May 2013) funded by the European Commission under the Technology-Enhanced Learning programme. This case study presents a successful application example of the Dynamic Roadmapping framework, as a new form of systemic, participative roadmapping approach for mainstreaming complex innovations; complex both on the supply side with multiple developers, and on the adoption side with multiple decision makers. It has evolved in the field of Technology Enhanced Learning (TEL), in schools and higher education sectors, but the specific case study presented here is related to the schools sector with special focus on: ***'changing schools to creative learning environments'*.**

A ***'co-innovation group'*** of European stakeholders was formed with the main purpose of driving towards a better TEL future, through broadly coordinated innovation focused on school as the hub of a creative learning environment. In this approach a co-innovation group works at a meso level (multi-organisational), bringing together an eco-system of interdependent stakeholders with the goal of generating a roadmap based on their shared desired futures and their goals and activities.

This section begins with information about the scope of the case study in terms of its meso level roadmapping. A more detailed analysis about the content issues of this case study was provided in Chapter 4, Section 4.2, in terms of the relevance of the case study to systemic innovations and to the Dynamic Roadmapping approach, the organisational structure of the of the case study, its duration, the participants, the membership protocol and the methods and tools used (see table 11). Chapter 6 continues with some key aspects of the case study such as: the formation of the co-innovation group from multiple key stakeholders and the analysis of the Observatory function. This is followed by the workshops process, through which, the co-innovation group: arrived at its shared desired future; produced an initial roadmap; undertook a scenario planning exercise; then tested the roadmap against four context scenarios; added corresponding possible alternative pathways; and lastly, recognised that, to address the wide variety of educational systems, the starting point for the roadmap would also need to be adjusted accordingly. At the end of this chapter, a summary of the insights specific to the creative classroom theme were provided.

6.1 Case study: Meso level Roadmapping Theme

This case study presents an example application of the 'Dynamic Roadmapping' framework as a new form of systemic, 'Dynamic Roadmapping', aimed at mainstreaming complex innovations - complex both on the supply side, with multiple developers, and on the adopter side, with multiple decision makers. The case study describes the implementation of the

[26] TEL-Map, a European Commission Seventh Framework Project (IST-257822) www.learningfrontiers.eu

‘Dynamic Roadmapping’ framework by the **TEL-Map project,** which brought together a variety of players already working independently towards building schools as ***‘creative learning environments’.***

TEL-Map project was a *Coordination and Support Action (October 2010 – May 2013)* funded by the European Commission under the Technology-Enhanced Learning programme. The case study has evolved in the **field of Technology Enhanced Learning (TEL), in schools** education sector with special focus on the **creative classroom theme**: **“changing schools to creative learning environments”**.

A *co-innovation value* network of European stakeholders was formed (co-innovation group) with the main purpose of driving towards a better TEL future through broadly coordinated innovation focused on school as the hub of a creative learning environment.

Meso level roadmapping

In this approach, a co-innovation group works at *a meso level (multi-organisational),* bringing together an eco-system of interdependent stakeholders with the goal of generating a roadmap based on their shared desired futures and their goals and activities. The co-innovation group is driven from the point of view of implementation, in order to bring the “whole system” together in a working value network. This includes a critical mass of participants in order to tackle, resolve and plan solutions for TEL that it would not be possible to be achieved by individual actors working alone, but would have an improved likelihood of being implemented in the different systems of the ecosystem. It thus introduces an approach to systemic change in schools education. For more details about the case study theme and the rational for choosing TEL as an implementation case of the ‘‘Dynamic Roadmapping’ framework please refer to section 4.2.1.

6.2 The formation of the Co-innovation group

Forming and facilitating the co-innovation group

TEL-Map partners started with the construction of domain **cartography** for TEL. This was based on multiple consultations with the TEL communities (both face-to-face and online) as well as on desk-based analysis and surveys with TEL vendors and researchers. TEL-Map partners identified different events and trade fairs that TEL stakeholders usually attend, as well as their online collaboration platforms, and other social networking web-spaces where they interact. The partners co-located TEL-Map events with other events, enabling them to carry out activities such as interviews and surveys aiming to understand both the state of play in TEL and the future directions of TEL stakeholders. They also collected and analysed other TEL-focused Roadmaps and future scenarios. The PhD network also assisted in mapping research projects and TEL innovations during dedicated weakly sessions in two summer school events and follow up online collaborations. This initial cartography was created using methodologies based on dynamic modelling and discourse management approaches (‘capturing the voice of’ different communities, for example PhD students, researchers, vendors, publishers and practitioners) in order to capture, externalize, aggregate, map and contrast the views of relevant communities. In parallel, we investigated the TEL Unit's research and development projects and Networks of Excellence (such as PROLEARN, GALA, ICOPER and STELLAR), as well as the EAC TEL lifelong learning and education projects, in order to map the research approaches and pilot projects in the area and their related people networks. This work has been documented in the project's portal Learning Frontiers portal as well as in different semantically interconnecting contextual maps in Conzilla conceptual browser (Kamtsiou et al. 2006), (Naeve & Kamtsiou 2013). This provided us with an early understanding of the possibilities for new applications based on the potential promise of emerging technologies and the different networks of technology experts/advanced users/suppliers and other intermediaries whose focus was the use of TEL in the school sector. In this way we were able to bring in a wide range of stakeholder needs; early-adopter views on innovation opportunities; early prototypes; and early access to the results of roadmapping and technology studies.

A first possible list of stakeholders (and their organizations/ networks/ projects) to be invited to the co-innovation group was formed. This first list included the following roles categories: *industry leader*, *EU policy maker*, *government, innovator, researcher, leading-edge teaching practitioner*, *sector funder*, *school leader, technology expert*, *network representative.*
This initial list was updated using the Future search methodology principle of "Get the whole system in the room" and used their 5 key criteria for identifying co-innovation participants, for which they use the acronym ARE-IN (Weisbord & Janoff 2010).

Here is the actual list the TEL-Map partners generated using the ARE-IN criteria (see below):

- Politicians with a focus on TEL &/or Education and Training Policy
- Policy makers in Government ministries for Education & Training
- Leading educational thinkers, visionaries and innovators
- Education and training software developers
- Education and training service providers
- Education and training content providers
- ICT infrastructure providers
- Leading researchers in TEL related disciplines
- HR and Training Departments
- University Teachers & TEL strategists and decision makers
- University Students
- School Students

The ARE-IN acronym represents the people with the following characteristics:

- **Authority to act:** the decision makers in an organisation or community who can authorise or prevent certain critical actions. For example in this case, these were across Europe Governments responsible for schools education. These will typically be people from Ministries of Education, and in particular, those with a responsibility for the future development of education in general and, where in post, for TEL and schools sectors in particular.

- **Resources** needed to implement plans: those with time and/or money needed to implement the plan. These will be varied. For example in R&D, these will be those who fund TEL R&D at European and national levels; for those developing products and services, it will be the directors of development in TEL related companies; in the user sector (schools, universities, and private education providers), these will be the budget holders responsible for the purchase of TEL.

- **Expertise** in the issues being considered: often professionals, researchers, pedagogics or developers with specific knowledge and skills.

- **Information** about the topic that no others have: those who have first-hand knowledge about and/or experience of the area in focus. Again this will be varied, ranging from those with detailed knowledge of the use of ICT in various sectors, e.g. in Ministries of Education, Marketing Directors in TEL product and service companies, people in agencies that support TEL, such as EUN SchoolNet or JISC in UK, or writers and journalists.

- **Need** that is being addressed: those who are currently disadvantaged or suffering in the current situation, or who are the clients or customers if the area is a business domain, or inhabitants if it is a locality or region that is the focus. For example in our case, this will be those directly involved in learning and teaching, i.e. learners and teachers, particularly those involved in the use of ICT for learning, and of these those involved in leading edge practice. They will be in schools, universities, commercial and government training providers, both in-house and commercial training providers. Note that they may well be innovators in their own right and have much to add.

The ARE-IN check list is simple a tool for setting up a viable group drawn from disparate stakeholders. This then provides a working list of who is needed to implement a co-innovation roadmap. The co-innovation members will bring their varied and complementary skills, incentives and resources. It is unlikely that a complete co-innovation Group, with all the required key stakeholders, will be formed at the outset. For example we found commercial developers were reluctant to engage until some concrete proposals were formulated. But after the initial participants feel they have sufficient committed members, they can get started on the next initial planning stage. However, they need to be fully aware that the other key stakeholders will all have to be won over and engaged if the innovation venture is to be ultimately successful. The **ongoing cartography** and information of the emerging clusters are used in order to make informed decisions on how to expand the initial co-innovation groups (see sections 6.3.4, 7.2.2 and Observatory related sections 6.3, 6.4, 7.2.2, 7.3).

The **Adner's innovation 'value blueprints'** were also adopted later by the co-innovation group, which point to the need to involve and fully understand the role the following types of participants and the costs and benefits to them, when it comes to the later adoption stages of the innovation (Ander 2012. p. 85):

- End users of the innovations: who are the final adopters of the value propositions envisioned in the roadmapping vision scenarios?
- Co-innovators: complementors that need to co-innovate before the intermediaries can adopt the offer.
- Suppliers: what suppliers will be needed to build the offers?
- Intermediaries: who else stands between the innovators and the end customers? What changes do they need to make in their own practices and processes in order to adopt the innovations and pass them to the end customers.

In addition, the TEL-Map project partners provided *appropriate tools* to support the co-innovation group and enable them to provide input in the different modules of the process. TEL-Map used and adapted existing tools that the communities were familiar with and used like Conceptual modelling tools (e.g. CmapTools, Conzilla concept Browser), interactive tools (e.g. Skype, Adobe connect, FM-flash meeting), Content management tools (electronic portfolio system Confolio) and social networking spaces such as Facebook, LinkedIn and Twitter (see table 11).

6.3 The Observatory function in Co-innovation Roadmapping

In order to keep the co-innovation roadmaps dynamic and agile, their key drivers, desired futures, context scenarios, roadmaps, uncertainty dimensions and assumptions, all had to be fed into an ***observatory function.*** This function supports the co-innovation group's roadmaps implementation and update process. It includes scanning for relevant developments in the wider contexts in that the roadmaps are operating, which the observatory filters and then feeds back relevant alerts to the co-innovation group.

The observatory provides the co-innovation group with alerts related to:

- *Possible context scenarios for the domain.* This includes PESTLE analysis, trends, tensions, and factors of change, and scenario descriptions.
- *The relevant signal, observation or data (the sign)*. For example, weak signals, such as events and signs, which might affect the schools sector and the desired futures and roadmaps of the co-innovation group. These signals can be gathered via people sources such as a DELPHI function, or via recording sources using mining methods like bibliometric, blogs analysis, social networking analysis, etc.

- *The 'PESTLE type' of the alert.* For example classification and analysis of the identified signals in PESTLE categories. Similarly this PESTLE analysis was done both automatically using mining tools and recorded sources and by people from the intelligent network.
- T*he aspect/s of the co-innovation Group's concerns that is/are impacted.* These include state of the art and gap analysis (e.g. SWOT analysis of roadmaps), market relevance of the co-innovation's roadmaps.
- Suggested/possible actions in forms of *reports*, e.g. SNA analysis, Trends analysis, state of the art, gap analysis, market relevance of co-innovation roadmaps, weak signals analysis, future scenarios for TEL and TEL roadmaps, recommendations on co-innovation roadmaps, context maps of co-innovation roadmaps.

In particular the observatory provided:

- Analysis of trends and weak signals in terms of identification, recording and classification and their significance for the co-innovation roadmaps. It includes the dissemination/execution/visualisation of online Delphi studies, and results from independent surveys and analyses about TEL. Comments were also made directly on the conceptual maps of the co-innovation roadmaps, using the collaborative CmapTools space, and via the scop.it online journal, and feeds.
- Topic mining / Social Networking analysis and horizon scanning tools, which are also used to generate and visualise signals/alerts, and collect data through semiautomatic crawling and data mining technology on interesting TEL sites and blogging services. These outputs fed into the trends & weak signals analysis and state of the art and gap analysis.
- Resources on TEL futures (reports, publications, highlights, context scenarios, roadmaps, etc.)
- Information on new ways of learning, emerging learning paradigms and TEL pedagogies. These were assessed via a Delphi online survey. The results were classified and monitored at the portal and they were also provided to the co-innovation group in the form of specialised reports.
- A cartography of the TEL ecosystem in terms of the main issues, tensions, key players, key research and development projects, their activities, networks, social networking analysis, etc. The MediaBase and the Conzilla and Conflio semantic tools were used to model, and present the results. As well as creating and maintaining a network of innovative communities, researchers, TEL experts (providers and users of TEL), their affiliations, and activities.
- Market intelligence regarding the industry, PESTLE analysis, surveys with industry players, technology and applications lifecycles, state of play in TEL reports.

- Crowdsourcing was used at the portal in order to collect trends and positions/opinions on specific topics or problems but also on desired visions for TEL and different TEL approaches. This was a good way to find complimentary matches for the co-innovation group or assess tensions among the positions in TEL community.

The Role of the Observatory Function in the start-up phase

The observatory as a bottom-up process provided the mechanisms to ensure the TEL stakeholders groups' involvement in the co-innovation group, by identifying others, who shared their views, goals, and concerns, thus building on the real needs and requirements of learning communities. The aim of this approach was to encourage these international stakeholder communities to share their goals and achievements, their networks, artefacts, visions and individual roadmaps with the observatory, and through this, with active European TEL projects, and industry players, policy makers, etc., so that each participating TEL stakeholder community in Europe can better understand what is going on within other participating TEL stakeholder communities. This initial cartography of TEL assisted in the creation of the co-innovation group.

The Role of the Observatory Function in the roadmap implementation phase

However, when the world becomes very turbulent, many assumptions that might normally be made become uncertain, and the question then arises as to how to cope with this uncertain and changing wider context. The initial roadmaps and future visions produced by the co-innovation group stretch out just as far as the co-innovation group can see with any confidence into the future, with guessed at branching alternative routes beyond that. As they progress, the next stretch becomes clearer and further branching alternatives are allowed for. They may find new and unexpected obstacles emerging that have to be addressed. Equally, they may find an unexpected short-cut, or a new factor that might provide something that accelerate or make their uptake easier. During this stage, an important part of the observatory progress was to look for signs that indicate what the co-innovation group is going to come up against next, whether expected or unexpected. It is the steady flow of resulting observations that are critical to 'Dynamic Roadmapping', identifying up obstacles to work around, better routes to the destination, or, in the extreme, modifying the destination, whether for better or worse - or just different. The co-innovation group used this analysis to update their context scenarios, and if necessary their desired scenarios and roadmaps. In addition, in each phase, the Observatory was also responsible for preparing an up-to-date survey of the relevant current state of the art and the state of play in TEL. This enabled the co-innovation group to stress test its assumptions about their roadmaps' starting point and modify them as necessary, thus provides further direct input to co-innovation participants' immediate planning processes.

The role of the Co-innovation participants

The co-innovation group needs to:

- Plan their own activities in the light of their common roadmaps and share these with the others and with the observatory. They likewise share their subsequent progress reports against these plans.
- Join with the observatory in horizon-scanning activities, contributing any relevant information that they find (bidirectional feedback between the observatory and the co-innovation group).
- The co-innovation group provides information to the observatory about: their Shared desired Futures, trends and factors they have identified that might influence these futures, futures scenarios that these futures might be played out, and their initial roadmaps. This information is used by the observatory as scope and indicators in order to scan for signals of change.
- As necessary, the observatory alerts the co-innovation group to significant signals they have picked up, to relevant unexpected developments, and to trends that appear to be changing their trajectories, indicating where they think revisions may need to be made. The co-innovation group then has to decide whether, in order of decreasing likelihood but increasing severity, whether to update their roadmap, modify their context scenarios, adapt their desired future, or, in the extreme case, abandon the whole project as no longer feasible.
- Any changes they make are then fed back to the observatory (see Figure 82).

This monitoring and feedback loop from the observatory, coupled with the feed forward of adaptive changes from the co-innovation group is the essential loop in the adaptive and agile stage of the 'Dynamic Roadmapping' process.

6.3.1 The structure of the TEL Roadmapping portal

The principle of separating the actual roadmapping process from the intelligence information and analysis streams was followed at the learning frontiers portal. The portal[27] (Drupal based) provided main types of spaces: a) Public observatory space and b) private co-innovation Roadmapping working spaces for the co-innovation groups. The observatory type of activities and results were organised, classified and presented in the public space of the **portal** called **'Emerging futures observatory'** under four tabs: '*Emerging Technologies', 'Signs of Change'*, '*Innovative learning practices', and 'Other's TEL futures'* (see Figures 83,84,85). The analysis from the research TEL projects was presented in a separate '*Projects'* space that also allowed for key multi-criteria word search (see Figures 114 & 115). The co-innovation groups were provided an internal web space called *'creating futures roadmaps'* used by them in order to publish and discuss their internal and final results of their roadmapping activities. The creating future roadmaps space provided also links to their Google documents, CmapTools, and Conzilla maps.

[27] http://www.learningfrontiers.eu/

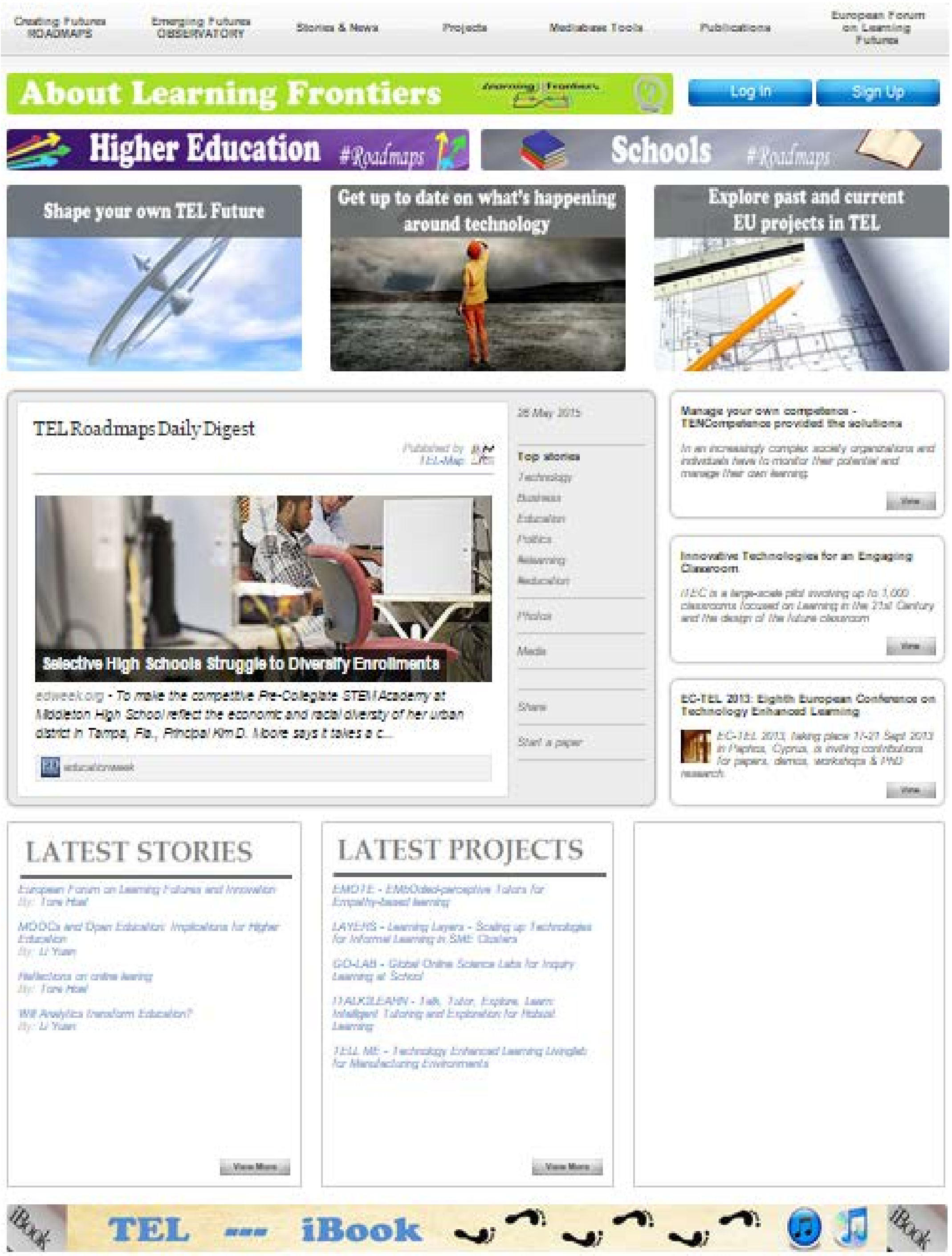


Figure 35. Learning frontiers portal front page snapshot *http://www.learningfrontiers.eu/*

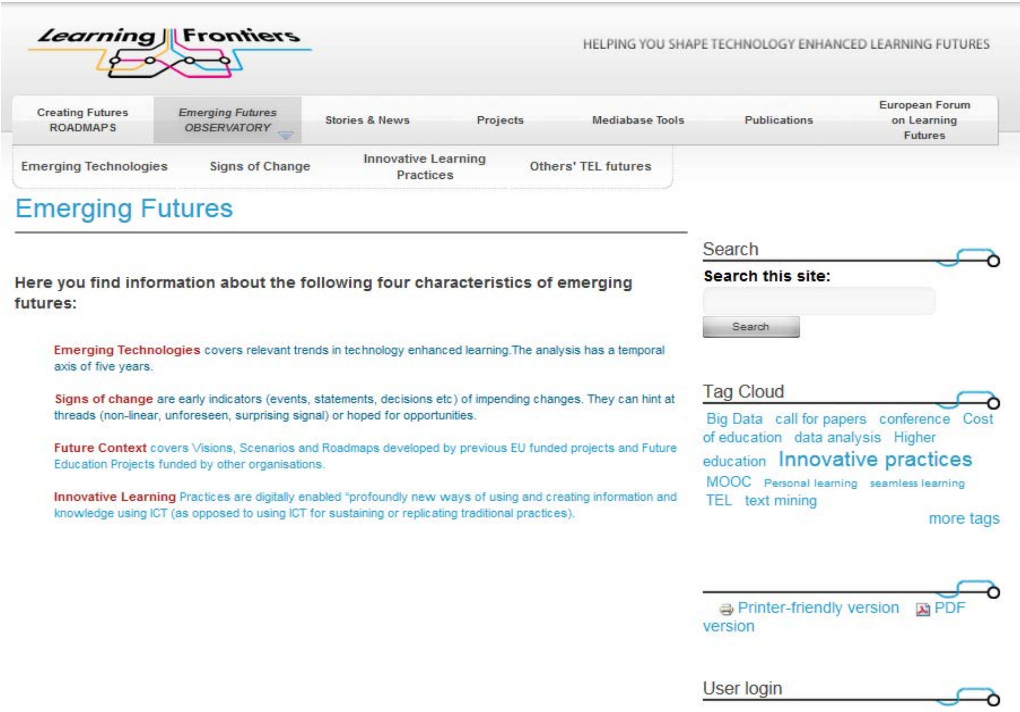


Figure 84. Emerging Futures Observatory page at learning frontiers snapshot
[*http://web.archive.org/web/20131006235316/http://learningfrontiers.eu/?q=emerging-futures*](http://web.archive.org/web/20131006235316/http://learningfrontiers.eu/?q=emerging-futures)

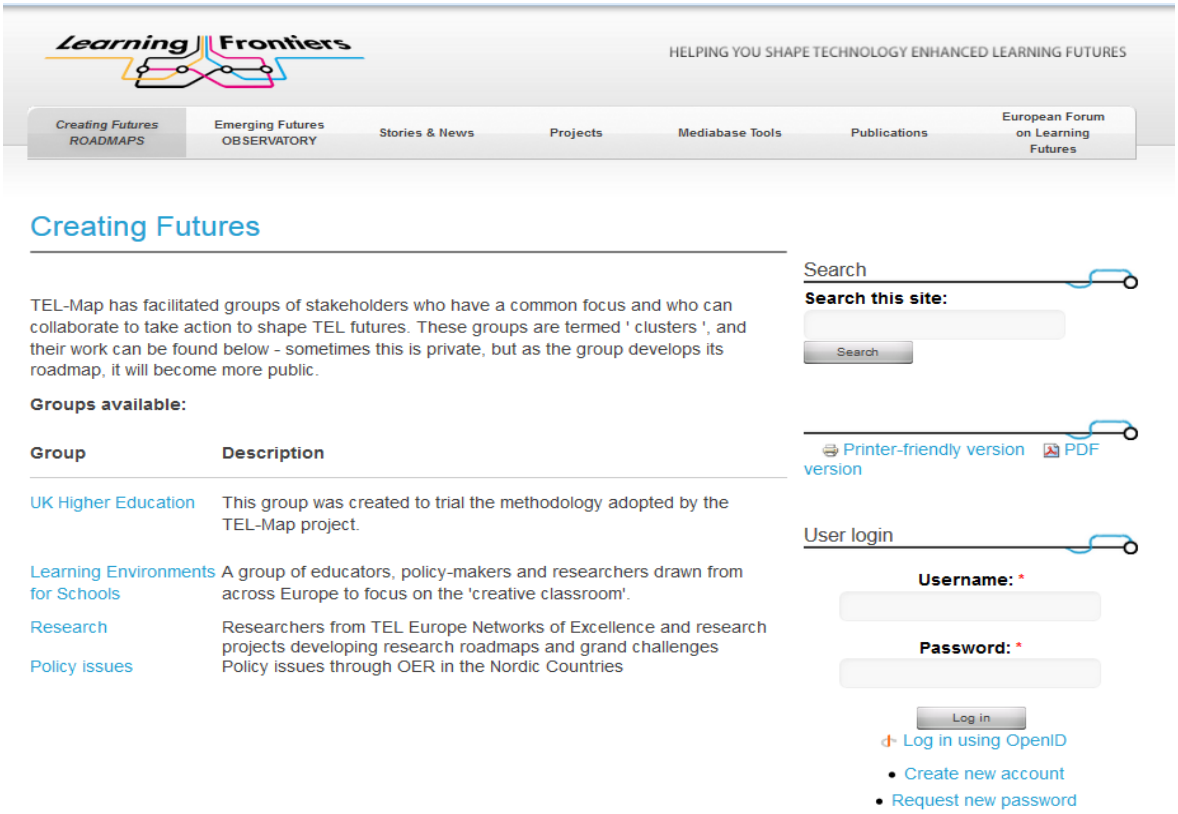


Figure 85. Internal web space for co-innovation groups at learning frontiers snapshot

Intelligent network tool box customised for 'Dynamic Roadmapping' in TEL-Map

In order to build our Technology Intelligence network, a tool box was needed in order to identify areas of significant resources inside our network and areas that were outside.

Therefore, the following questions were considered:

- Which tools, what methods, which Resources and where, who?
- What types of information resources?
- What types of Foresight, Technology Intelligent and Roadmapping outputs (reusable formats)?
- What type of processes: SCAN and MINE, ANALYSIS?

The observatory function used two different sources of information, people sources, and recording digital info sources.

- ***People sources*** for example, surveys, interviews, capturing the voices of innovative communities, Delphi, stakeholders' consultations, and the co-innovation group's activities and analysis.
- ***Digital info sources*** for example, tools and methods that allow for topic mining, text mining, bibliometric and social networking analysis, etc.

6.3.2 Digital info sources and tools

Digital tools and methods used to build the observatory included topic, text mining, social network analysis (SNA) tools, Twitter feeds and bibliometric tools. A social media observatory function was provided, using the MediaBase (Aachen 2012) tool developed by TEL-Map partners at the University of Aachen. The TEL-Map Mediabase database maintained three relational databases, which stored and index information on TEL-related projects, papers, and social media artefacts, such as blogs and tweets. For TEL-Map observatory, the MediaBase was fed with data from the TEL blogosphere, from TEL projects and TEL bibliographies. Media Base as a backend was crawling and indexing relevant TEL web sources EU funded TEL projects: 134 projects from – eTEN, FP6/7, eContentplus, PSP, and from Blogosphere: 582 TEL blogs with 89.600 … approx. 750 per Year. The Mediabase tools were also available via the portal for any innovative community or stakeholder who would like to install them and make their own data analysis. The MediaBase tools were grouped in three main categories (see Figure 86): a) D-Vita Visual Topic Analysis, an interactive visual topic dynamics analysis tool, b) Learning Frontiers dashboard, a personalisable dashboard of data visualisation widgets, c) AERCS publications and authors, a tool to analyse publication venues and authorship networks. The Confolio semantic content management tool developed by the KTH partner was served as the backend content management and customer Relation Management (CRM) tool of Learning Frontiers portal. It provided electronic portfolios for TEL stakeholders in order to describe, classify, publish, semantically link and share their work and networks. Conzilla and CmapTools were provided as conceptual modelling tools for the TEL community in order to collaboratively model, publish, annotate, and share their roadmaps and other TEL maps. These tools were also used in order to build the TEL cartography concentrated on extracting signal out of publications and interviews. In addition, a 'project space' provided an interface to Mediabase's Projects interface. It offered functionalities to browse and search EU TEL projects and research partners. The information in the projects space was both accessed automatically from the EU Cordis website, and from semantic information supplied by stakeholders in Confolio tool. A geographical 'projects Geomap' was also provided to visualise country specific information searchable by the users.

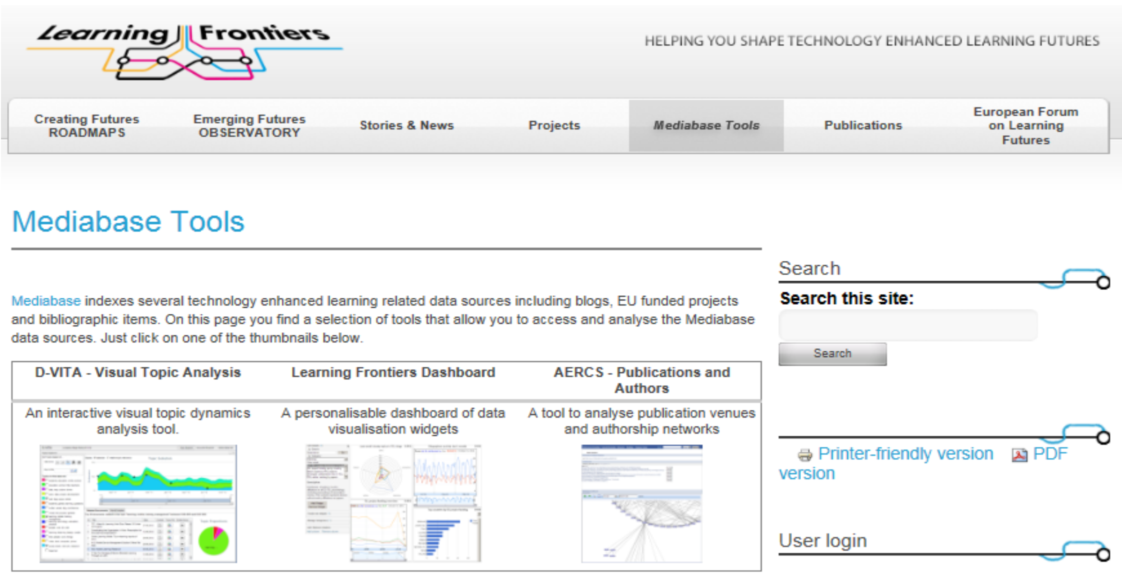


Figure 86: Media base tools, learning frontiers snapshot

Social Network Analysis (SNA) of innovative communities and actors

This analysis included not just people, but also their activities, related projects, publications, conferences, networks, etc. SNA provided interactive visualizations and network metrics for these social networks, and indications about the most important actors from a wide range of perspectives as well as future directions and insight into collaboration and communication networks in different types of media and settings (Cooper, Pham, et al. 2011).

The following Table 13 shows an example of the SNA analysis in relation to topic mining in Mediabase (Cooper, Pham, et al. 2011).

	Social Network Analysis	Topic Mining
TEL Papers	• Most central authors in TEL • Most frequent collaborations on TEL papers • Most important TEL conferences and journals • Development characteristics of authorship networks in TEL conferences.	• Rising and falling terms in TEL paper abstracts and keywords • Topics addressed by most important TEL authors/papers
TEL Projects	• Consortium progression between projects • Partner collaborations across TEL projects • Most central organizations in TEL projects • Most central TEL projects • Development of SNA metrics in project collaboration network over time	• Topic distribution and shifts in TEL project foci over time • Funding and partners related to topics in TEL projects
TEL Media	• Citation network in TEL blogs • Most central web sources referenced in TEL blogs • Authorities and hubs in the TEL blogosphere • Co-occurrence of words/bursts in blog entries	• Topic bursts in TEL blogs over time • Recently appearing topics • Topics with a rising frequency over the last years

Table 2. SNA analysis and topic mining in the TEL-Map Mediabase. Source: table 1, D4.3 Mediabase Ready and First Analysis Report (Cooper, Pham, et al. 2011)*, page 10*

Topic mining analysis and text analysis

Topic analysis was used in order to visualise which topics were of rising or falling interest in the wider world (Cooper, Pham, et al. 2011). To analyse topics and visualize dynamics in the Mediabase data, the partners developed and deployed the visual analytics tool D-VITA[28] . This allows stakeholders to explore easily in their web browsers, aspects of topic dynamics in TEL research projects, in conference papers and from blogosphere data sources (see Figure 87).

[28] http://www.learningfrontiers.eu/?q=mediabase

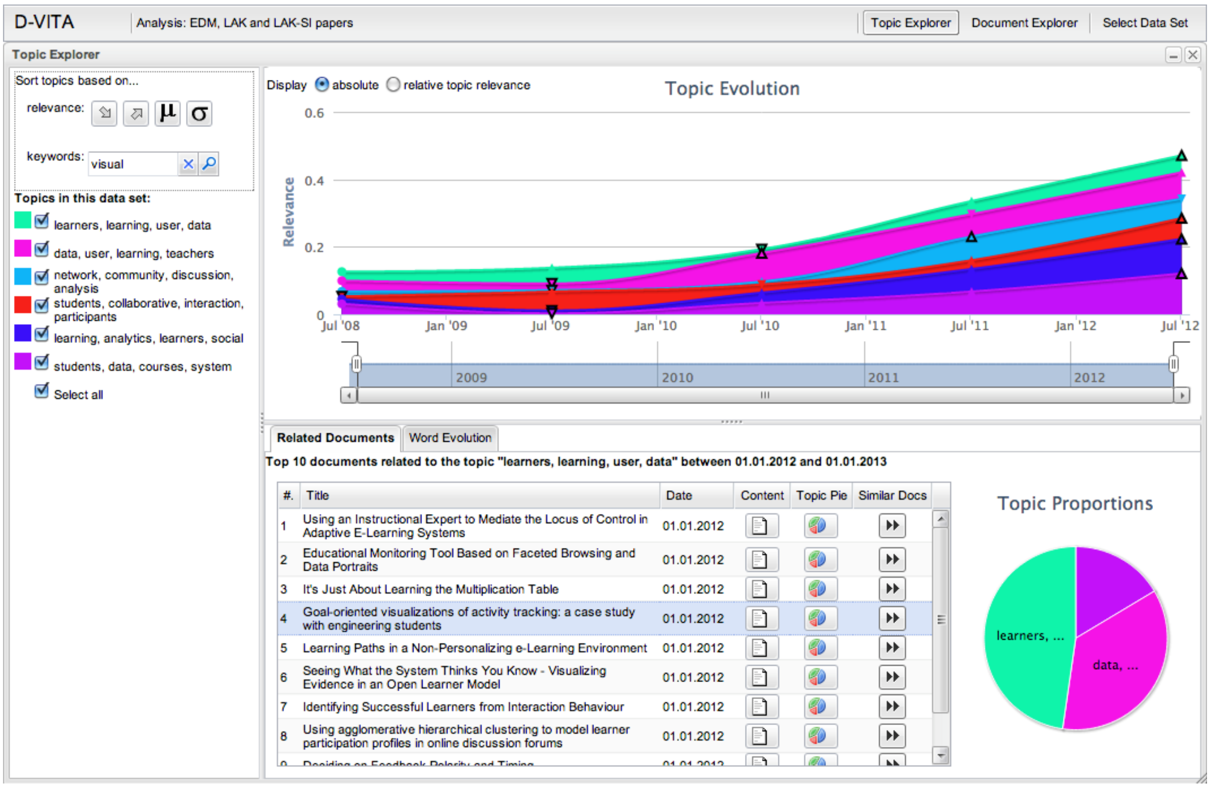


Figure 87. Mediabase D-VITA Intelligent document browser tool

Topic Analysis was also an effective method to overcome bias or topics closer to the comfort zone of the co-innovation group. Such function provided intelligence to co-innovation with an analysis of topics that might be of interest of other communities or outside the typical TEL domain and the radar of the co-innovation group. Figures 88 and 89 show two examples of such trend analysis. The first example Figure 88 is using *Google Trends* to explore the trend in MOOCs. First the user is accessing http://www.google.com/trends/, entering the topic and selects a category (e.g. Education), time-period or geographical range. This analysis provides a good indication of what people are searching for, when they are first interesting about a topic and when their interest declines, etc.

The second example Figure 89 shows how the *TEL-Map History Visualiser tool* was used to further explore the 'MOOC' trend and provide information about what people are blogging. This tool was developed by the partners responsible for the portal tools as a self-service analysis tool, which used the blog content harvested by the blogs monitored by Mediabase. The tool provided a statistical analysis which determined a trend line (with confidence limits) and provided indication about when the word appears in blog posts together with words that indicate positive emotion (e.g. optimism, approval). As demonstrated by the two examples, the analysis if the term MOOCs shows much more interest in blogs rather than in the wider community searching in Google.

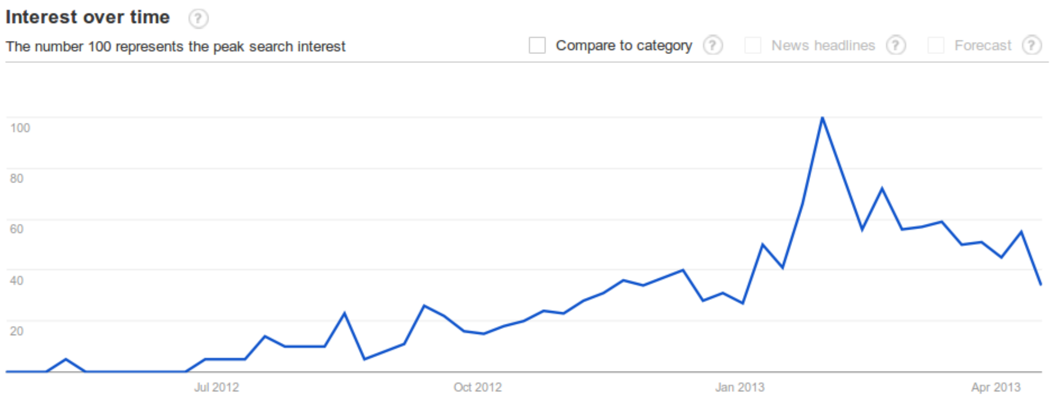


Figure 88. Example: Using Google Trends to Explore Trend in MOOCs. Google Trends frequency of search term "MOOC" in the 12 months to April 2013, filtered to category "Education". This chart can be accessed: www.google.com/trends/explore#cat=0-958-74&q=MOOC&date=today 12-m. Adapted from (Kamtsiou, Olivier, et al. 2013) *from figure 5.4, p.70*

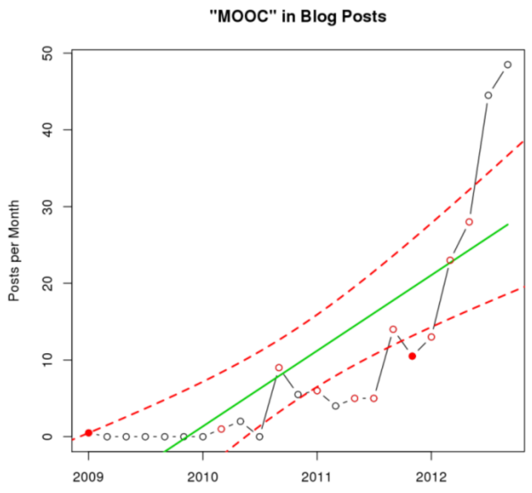


Figure 89. Example 2: Using the TELMap History Visualiser to Explore Trend in "MOOC" Blogs Available at: http://crunch.kmi.open.ac.uk/people/~acooper/services/TMWS/HV/HV.html.

Com-pair tool was created to compare information from two recorded sources. This tool provided an indication on some differences between the more frequent themes in two sets of data. This approach was used in order to reveal how the important of topics varies between different communities. Differences showed up where there was not a single narrative of emerging TEL and might indicated sources of disagreement. One example of the Comp-pair method was the comparison of the full text of ICALT and ICCE conference papers for 2011 that was published on the Learning Frontiers website[29] was undertaken using Com-pair (Voigt et al. 2012).

[29] http://www.learningfrontiers.eu/?q=story/east-and-west-two-worlds-technology-enhanced-learning

PESTLE Mining involved the use of a simple classifier 'the PESL classifier tool' to provide an automated PESL (Political, Economic, Social, and Legal) analysis of trends and signs of change (See Figure 90). This was done via keywords which related to PESTLE contexts and text mining of blog posts. Since it was observed that social category was not particularly reliable, it was dropped from the PESTLE analysis.

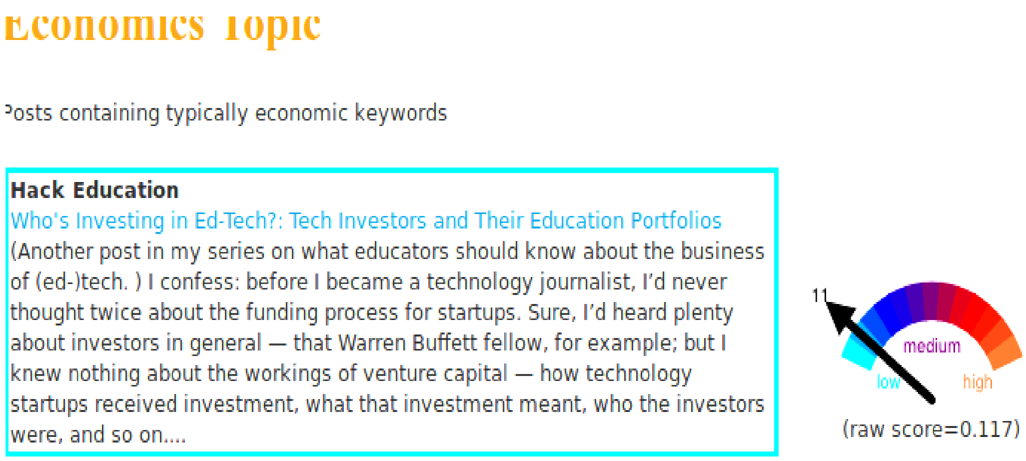


Figure 90: PESL classifier example of blog analysis, Economic Topic. Adapted from (Voigt et al. 2012) *from figure 9. p15*

Figure 91 shows an example of PESTLE categorization of weak signals in the portal using blog discussions analysis and/or text mining of conference papers. Figure 92 shows the analysis of MOOCs as a sign of change and the open discourse with the users (agreements/disagreements).

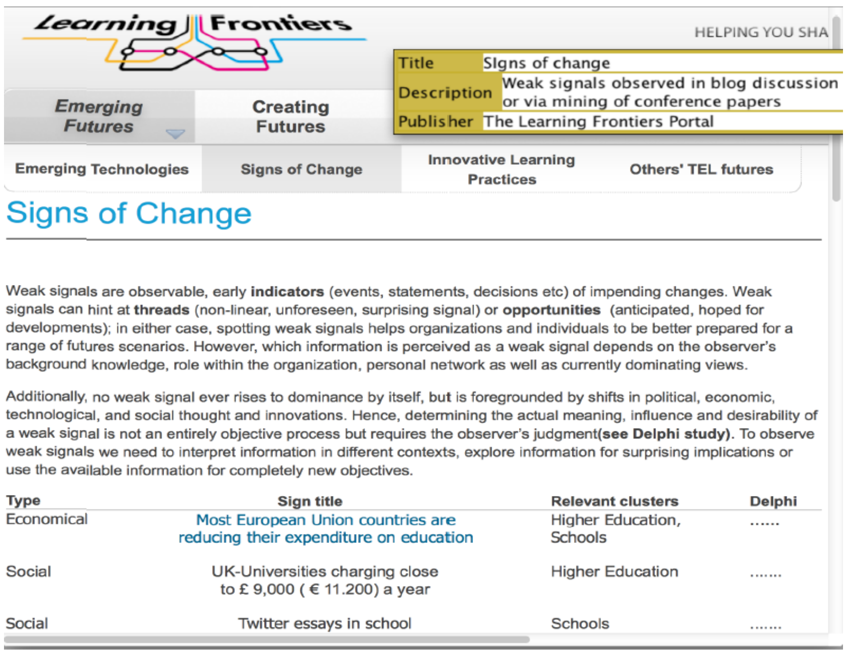


Figure 91. PESLE analysis of signs of change in TEL (weak signals) snapshot learning frontiers

MASSIVE OPEN ONLINE COURSES (X-MOOCS)

Fridolin Wild, Paul Lefrere, Katharina Freitag, Philipp Holtkamp, Christian Voigt

There have been many stories prophesying changes in how we learn with technology. MOOCs could be one of them or it might turn out to be a real game changer. Some initially weak signals became more central and turned into mainstream over time, others not. Great ideas cannot thrive by themselves; research, development, evaluation, deployment, procurement are activities planned and performed by interdependent groups (pursuing connecting interests), together with stakeholders this forms a highly complex and dynamic ecosystem. In this overabundance of information, it often is difficult to separate noise from important weak signals and false prophets from those who should be listened to. With this exposé , the TELmap project provides background and context to the corroboration of weak signals and possible policy interventions conserning MOOCs.

1 Conceptual clarification

In a critical review of MOOCs, Sir John Daniel remarked that 'the real revolution is that universities with scarcety at the heart of their business models are embracing openness' [16]. However, the way this is happening follows mainly two different innovation models: there are c-MOOCs, closely linked with connectivism (following Georg Siemens and Stephen Downes), and there are x-MOOCs, bringing existing courses to an extended audience. Whereas the former is aiming for innovative pedagogy, the latter is driving technological and economical innovation. This report is (for now) focusing on x-MOOCs.

5 Agrees | 0 Disagrees
→ To agree or disagree please log in or register.

Show 1 comment(s)

2 Examples for x-MOOCs

One of the first signs of change that indicated MOOCs might be on the rise was in fall 2011 when over 160,000 people signed up [1] for a course in artificial intelligence offered by Sebastian Thrun and Peter Norvig via Know Labs, which is now

Figure 92. Analysis of signs of change in TEL (weak signals) provided by TEL experts sources, snapshot learning frontiers

Daily digest on the portal: this service at Learning Frontiers portal provided TEL communities with an up-to-date daily digest of relevant websites, blog posts, and events in TEL. There were three sources used: a) content was sourced from the observatory's own twitter feed and b) from external twitter users, which the observatory intelligent and co-innovation teams were following and c) from tweets that reference the #TELroadmaps hashtag, which is the agreed twitter hashtag for TEL-Map. This twitter widget was collected and analysed blog posts coming from different sources *(Cooper, Pham, et al. 2011)* (see Figure 93).

Users could create new widgets or they could use existing categories such as: TEL projects, papers: TEL conference and journal papers, Blogs: TEL blogosphere, Ranking: Presents a ranking of data sources, Aggregate: Presents aggregated data, Comparison: Presents comparative data, Timeline: Presents data over time, Money/funds: Data related to funds and money, Geographical: Data containing geographical information, Bursts: Presents recent bursts in data, People: Data related to people, Radar: Radar chart visualization, Table: Tabular data presentation, Network: Presentation of data as a network, Pie: Presentation as pie chart, Histogram: Presentation as a histogram, Feed: Feeds, Social: Social widgets, Content: Access to educational content, Search: Search-enabled widget (Derntl et al. 2012).

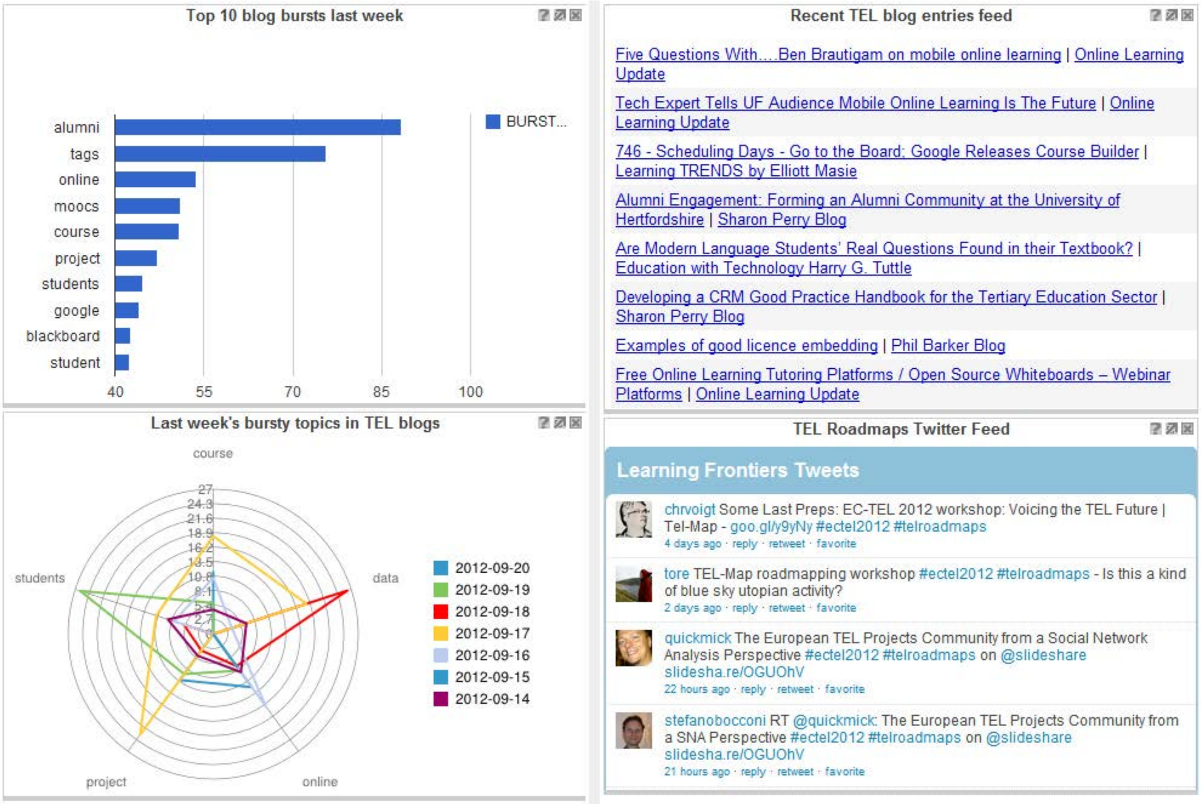


Figure 93: Learning Frontiers dashboard service showing four social media widgets. Adapted from (Cooper, Pham, et al. 2011) *from Figure 7, p. 17.*

Mediabase search box: this functionality allowed the co-innovation groups to search for Mediabase content relevant to their current work context. Both, the Emerging Futures (observatory space) and the Creating Futures (co-innovation space) offered a search widget which allowed for quick keyword-based searching and visualisation of TEL Mediabase entries from the past six months. In addition, the Observatory also monitored a list of specific technologies (e.g. with MOOCs, Game-based Learning, etc. in the Innovative Learning Practices and Emerging Technologies section). The search widget immediately provided an up-to-date list of relevant entries for a search term which could be pre-configured.

Research topics

Besides the analysis of the emerging topics and technology trends, the History Visualiser tool was used to analyse the terms appear in TEL related and around TEL conference abstracts during 2006-2011. Figure 94 is an example of visualisations created by the History Visualiser tool. It shows how often the terms “mobile” (blue), “smartphone” (green), “tablet” (yellow) and “ubiquitous” (orange) appeared in the abstracts of papers published in the proceedings of the conferences ICALT, EC-TEL, CAL, ICHL and ICWL.

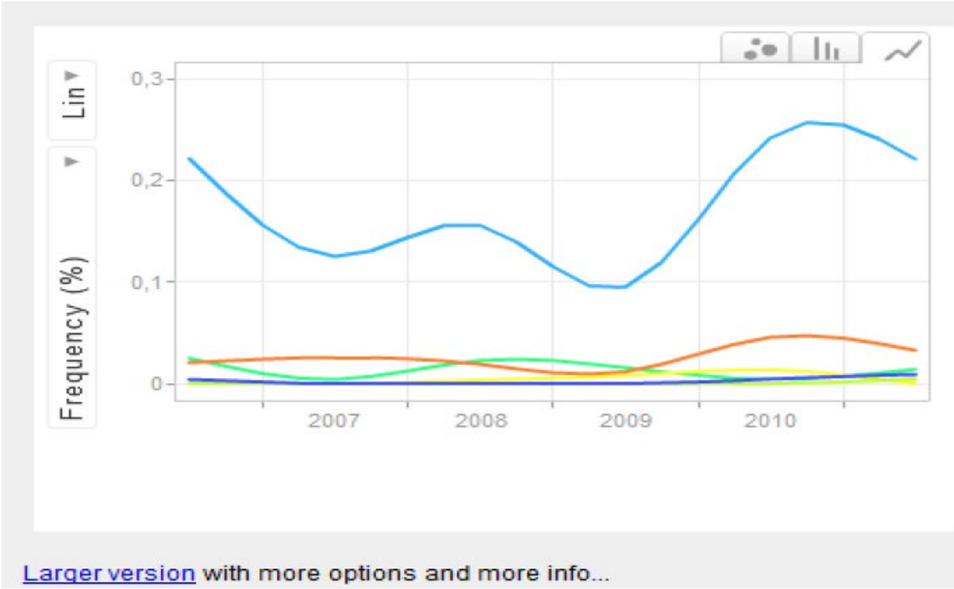


Figure 94: Conference authors interest example. Interactive diagram created with History Visualizer. Adapted from (Cooper, Pham, et al. 2011) *from Figure 5, p.12*

The learning Frontiers dashboard

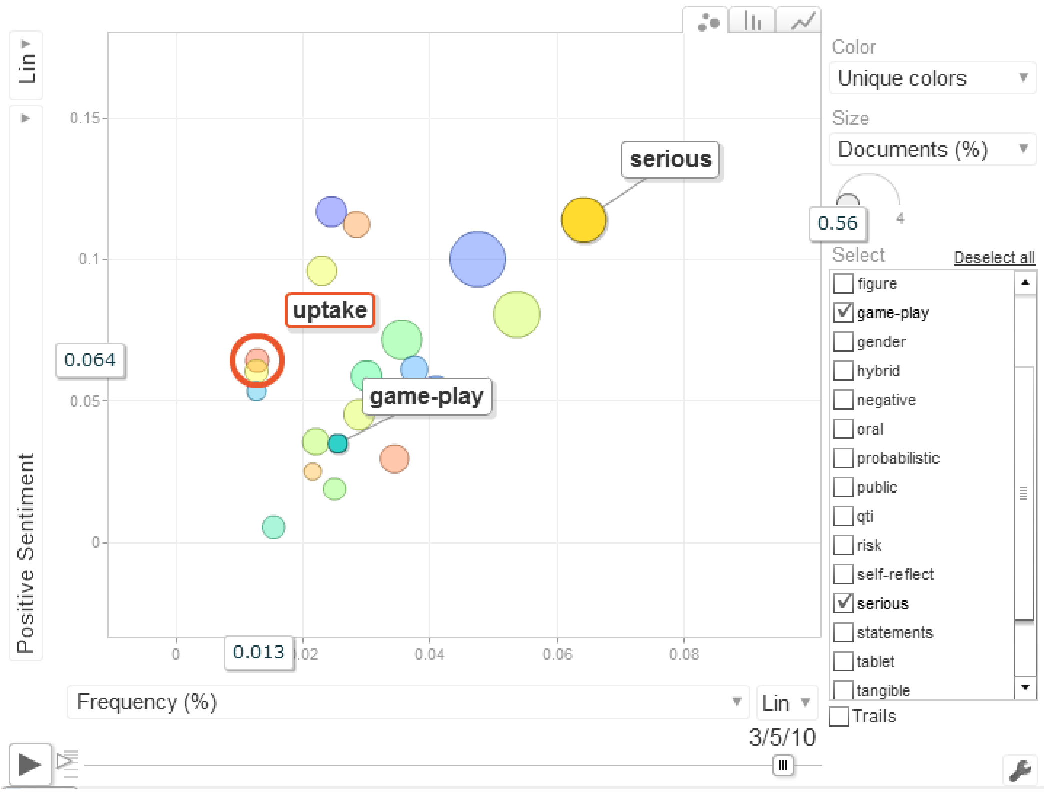


Figure 36. Dashboard widget. Widget displaying rising and falling terms in recent TEL conference papers. Figure adapted from (Cooper, Pham, et al. 2011) *from figure 6, p.13.*

The learning Frontiers dashboards provided the digital data services in form of **multiple widgets** and feeds. It provided a visualisation and analysis about terms which got increased attention in 2010 from a low level in the previous 4 years in the conference proceedings of ICALT, ECTEL and ICWL (see Figure 95).

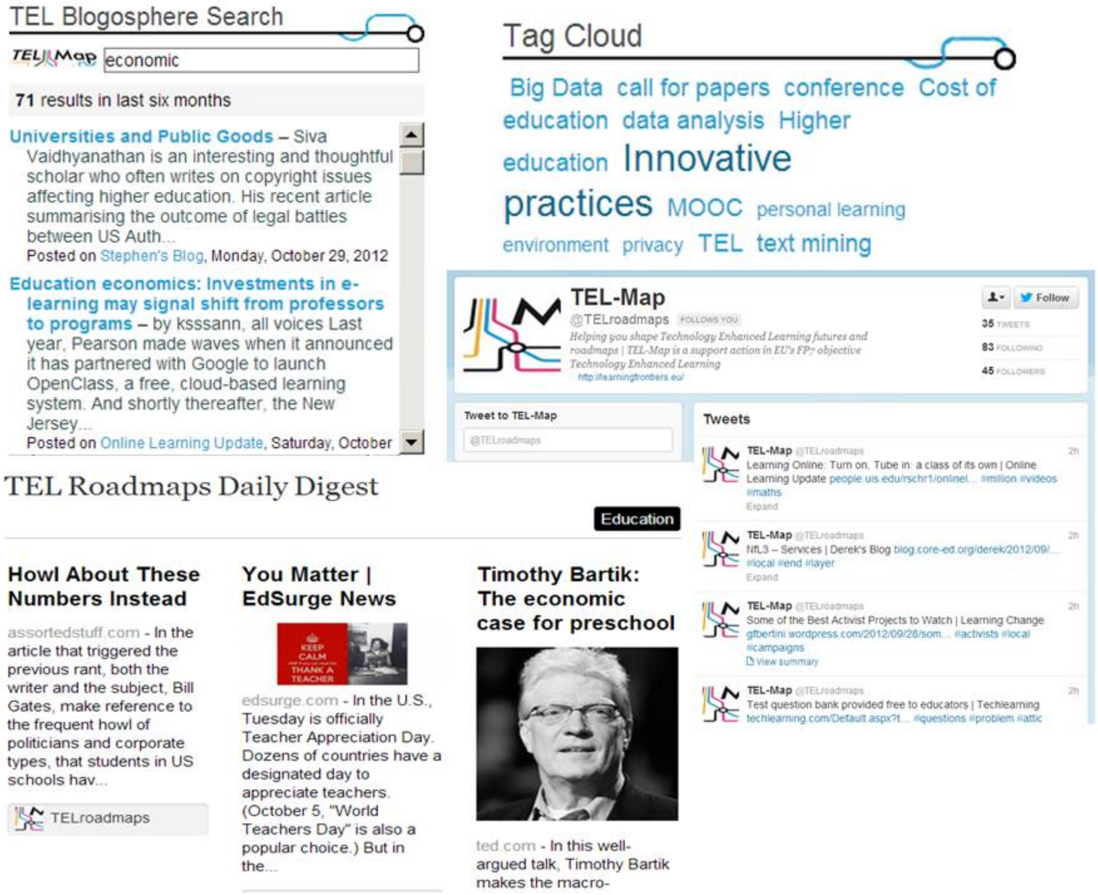


Figure 96. An illustration of Blog analysis examples from learning frontiers website (snapshots)

Scoop.it was a Social Media tool implemented in the portal in order to support the co-innovation group. It is similar to a bookmarking service with content management functionalities. A structure online journal was created via this application which provided daily news mashup from websites, blogs (see figure 96), tweets etc. Figure 97 shows an example of a Scoop.it-journal dealing with the topic ‘technology enhanced learning”. The Tool enabled the co-innovation group to suggest content for their network members. A member of the co-innovation group or of the intelligent network could search for content from other members using tags previously linked to specific topics.

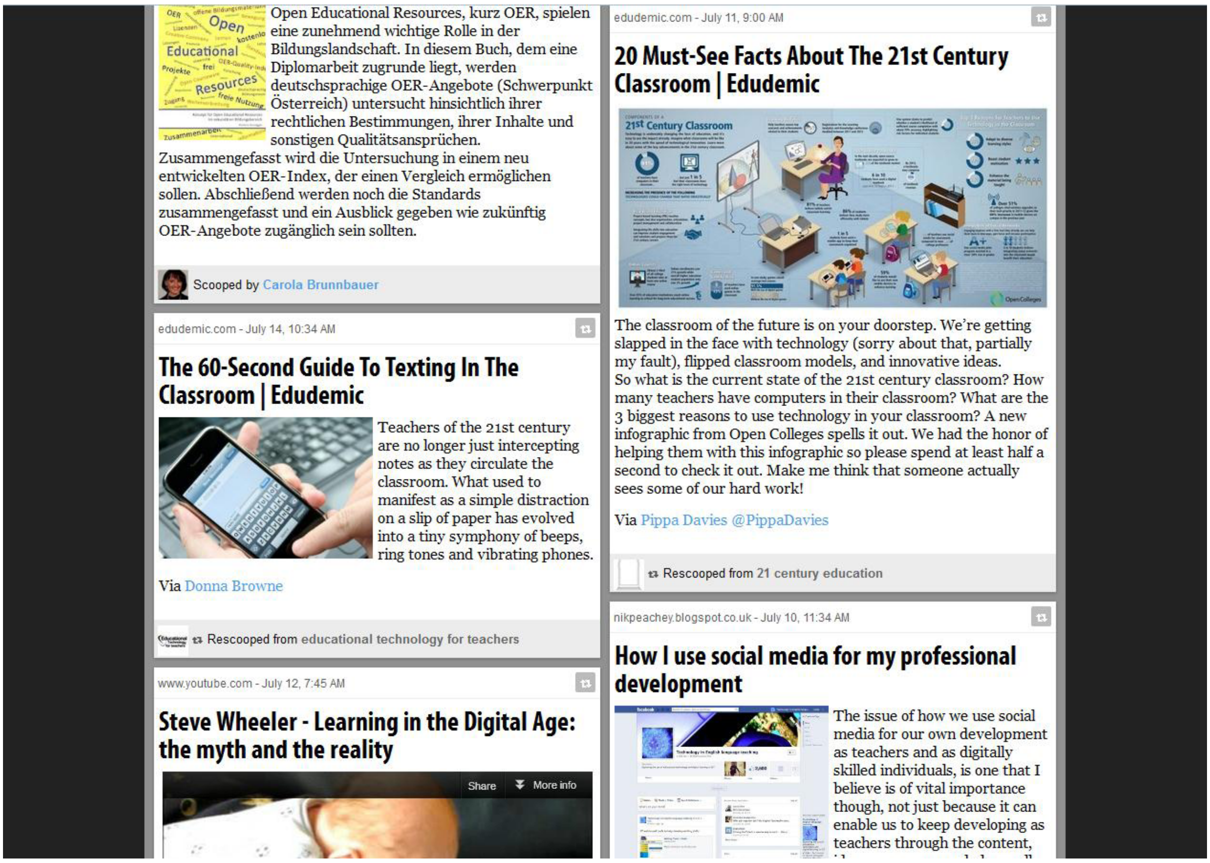


Figure 97. Scoop.it online journal about technology enhanced learning example. Adapted from (Cooper, Pham, et al. 2011) *from Figure 8, p. 16.*

6.3.3 People sources methods and tools

Policy foresight methods & Weak Signals

Practice and Policy Delphi methods were used in order to provide insights into emerging pedagogical paradigms and the related innovative learning practices. Forecast Delphi was used as a foresight method to provide information related to the expected time and the impact of specific new developments and innovative practices (likelihood to become true); Policy Delphi was used as foresight method, which surveyed the feasibility and desirability of specific policy interventions which were expected to channel or boost certain developments (Voigt et al. 2012), (Kamtsiou, Olivier, et al. 2013). Figure 98 below provides an example of the online practice and policy foresight templates in the portal. The partners used LimeSurvey, an open source survey application to run the Delphi activities. As set of innovative TEL practices were described based on an ongoing monitoring of indicators of change (weak signals) and the current focus in TEL conferences and fairs. These activities included a daily update of most often mentioned topics, the semi-automatic classification of postings into PLE categories (political, economic and legal) (see section 3.3.2). Weak Signals were extracted based on analysis from publications (e.g. text mining 2500 TEL conferences proceedings from ICALT, ECTEL, CAL, ICHL and ICWL conferences), interviews with 50 TEL providers, researchers and users, 22 research projects, from input provided from the Co-innovation group's workshops (especially workshop 1 and 2: see sections 6.5.1 & 6.5.2), from mining 7000 blog posts, 60 Tweets including TEL-Map's "#telroadmaps" and 5 innovative practices – Massive Open Online Courses, Microlearning, Gamified Learning, Flipped Classrooms and Seamless Learning - (contextualising 25 Delphi statements).

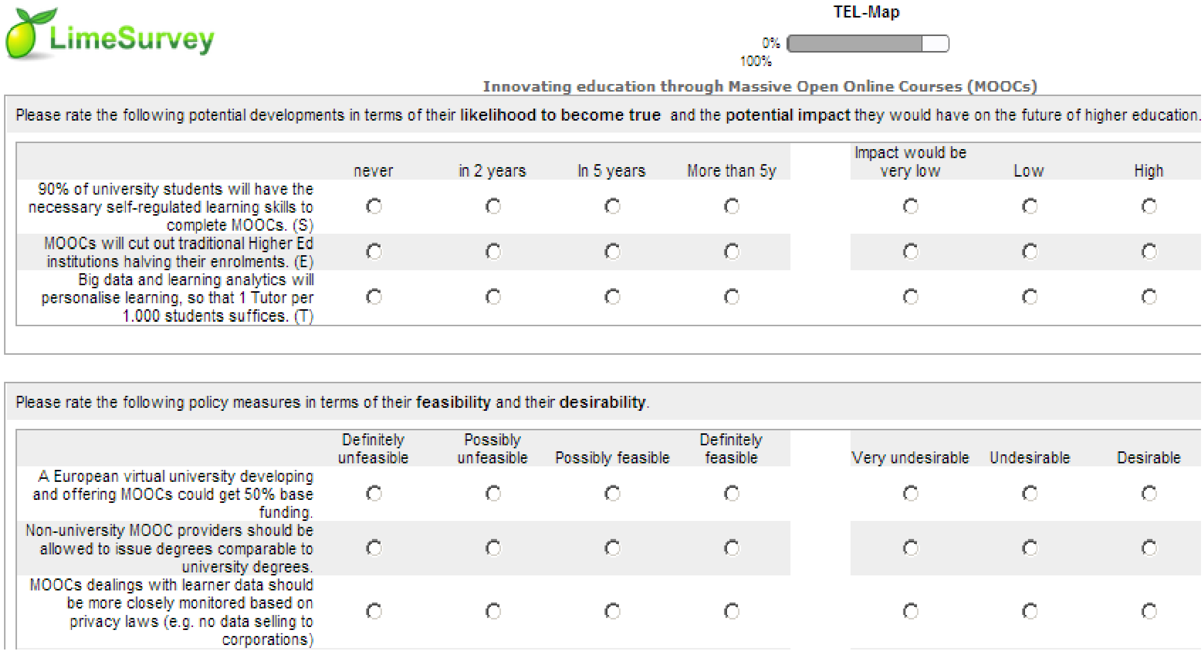


Figure 98. Policy and practice Delphi functions in observatory. Adapted from (Kamtsiou, Olivier, et al. 2013) *from figure 3.2, p.49*

Technology trends

Technology assessment was provided in order to get an understanding of the state of adoption of technologies in TEL domain. This involved mapping the results from technology surveys, desk-top research, analysis of the FP7 projects and from lifelong learning projects to a set of emerging technologies (e.g., mobile learning technologies, cloud computing, game-based learning, eBooks and eTextbooks, learning analytics, context-sensitive services, augmented reality and gesture recognition), which were then monitored by the observatory. For each technology trend, it was analysed which TEL research and development project adopted the technology, to what extent it was adopted and what was the motive for the adoption. Additionally, it was explored in which domain and by which target user group the technology was adopted (Giorgini et al. 2013), (Kamtsiou, Olivier, et al. 2013). The results of this analysis were presented in the emerging technologies section in the Learning Frontiers portal[30] and as a set of special report to the co-innovation group. The co-innovation group used these results for their gap analysis process and the updating of the initial roadmaps. These were done during workshop 5 and afterwards via online consultations among the co-innovation group and the observatory network.

Data sources used for the analysis of trends have included:

[30] http://learningfrontiers.eu/?q=emerging-futures

Online Questionnaire and Interviews: more than 50 TEL providers have been interviewed at Learning Technologies, LearnTec, ITK2012 (Interactive Technology in Education) or contacted at E-Learn Expò and involved, with other contacts by the observatory network, to the online survey on learning technology trends.

Analysts' reports: predictions on future learning technologies from Ambient Insight, Gartner, Cisco, Cegos, Ovum, and Doloitte have been considered.

Public TEL studies: reports from Horizon, Stellar, GROE and Towards Maturity have been analysed.

Scientific publications: an automatic data mining on more than 2500 TEL conferences proceedings (from ICALT, ECTEL, CAL, ICHL and ICWL) and blogs was conducted to show the frequency of the terms of trends (e.g. “cloud”) and the average "subjectivity" of abstracts containing the terms; in addition, the same sources of data have been used to generate graphs which summarise the words preceding and following a chosen word (or group of words e.g. "learning object" is possible). These graphs provide a supplementary aid to interpretation of what the trends are.

FP7 TEL projects: 22 TEL projects have been deeply analysed in order to extract the projects' technologies, their maturity level and drivers. The work has seen the involvement the projects coordinators and the study of project web sites and online project documents.

Capturing the voices of innovative communities

The ‘capturing the voices of innovative communities' methodology was a process comprised of the following steps (Kamtsiou, Olivier, et al. 2013), (Naeve & Kamtsiou 2013):

1. *Event scouting:* an event took place, for example, industry trade fair, scientific conference, Workshop, PhD Summer School etc.), where TEL-Map partners from the roadmapping facilitation team and/or the intelligent network address the stakeholders and capture their ideas.

2. *Initial modelling* of the discussions by the modelling team, who mapped the answers, differences, statements, people, groups, etc. In this case the Conzilla/Confolio tools and CmapTools were used.

3. *Exposing the results at the portal.* As a story, as a project aspect, as an emerging trend, or an emerging learning practice in the roadmapping emergent future tabs, or directly in the co-innovation group space depending on the situation.

4. Allowing the stakeholders *to discuss and comment* on the aspects within the portal with the discourse management services. This step included engaging stakeholders for a debate and discussions in the portal. Delphi tools with survey functions were also used. Additionally, the results were modelled and presented in the Conzilla browser and were included in various reports by the observatory.

5. *Observing, learning and capturing the voices* within the Learning Frontiers portal

6. *Re-modelling.* Updating the models and semantic relations within confolio/conzilla.

7. *Exposing results in the portal*, also utilising social media functions such as tweeter, Facebook and linked-in and the Media-Base.

6.3.4 Modelling using the Conzilla and Confolio tools

Conzilla conceptual modelling tool

The **Conzilla** conceptual modelling tool was developed by the KMR group at KTH (Royal Institute of Technology, Stockholm), and it was used in order to model, semantically link, store and extend the knowledge and foresight of the TEL innovative communities. Conzilla provides an interface for editing and presenting information on the semantic web. It simplifies organization and presentation of digital information by making *it possible to investigate concepts and their associated content, in different contexts.* Thus, Conzilla[31] provides the functionality to develop, organise and present models in a way that the different *concepts* and their *relationships* can be explored in different *context maps* (Naeve et al. 2006). Moreover, a variety of types of content such as web pages, documents, images, movies, references to books or geographical places etc. can be linked to concepts and concept-relations and accessed. When new content is added, Conzilla automatically detects when the same concept occurs in several context-maps and allows you to navigate between these context-maps. It also supports regular hyperlinks, which provides the possibility to link a concept or concept-relation to another context-map (called a detailed map). The basic principles for how a concept browser operates have been developed by the KMR group since 1998. Conzilla is developed under an open source license and provided by KTH to TEL-Map at no cost. For more information see (KMR group at CID 2010). When first designing the Observatory tools, it was foreseen to only use Conzilla as a modelling tool, but since the KTH (Royal Institute of Technology, Sweden) plans to further develop Conzilla (Naeve, 2001) to a web-based collaborative modelling tool did not materialised, we had to also use *CmapTools* in order support the *collaborative modelling efforts* of the co-innovation group (Naeve & Kamtsiou 2013). Some examples of Conzilla maps are presented below, in order to illustrate how the various concepts of the co-innovation roadmap, the co-innovation roadmapping processes and their outputs were modelled, mapped and interlinked. It also provides examples of how different intelligence from research, policy and industry were mapped and integrated, thus capturing the voices of different innovative TEL communities, without forcing consensus, but rather indicate opportunities for collaboration. This collaboration finding opportunities were reinforced via the electronic portfolios of communities, projects and TEL researchers (See Figures 110, 113, 114, 115, 116) developed using the ***Confolio tool***[32] and by the SNA analysis done automatically in the portal. The integrated platform of Conzilla and Confolio tools together with the MediaBase tools formed the backend support of the Learning Frontiers portal. They provided support for managing the

[31] www.conzilla.org
[32] http://wiki.organic-edunet.eu/index.php/Confolio

innovative communities, their activities and models, with the help of electronic portfolios and granting access to new community members. Finally, another example illustrates how the observatory analysis was mapped to the co-innovation roadmaps produced by the co-innovation group.

Figure 99 depicts the '*TEL-Map start map*', which shows the synergetic integration of different types of TEL roadmapping communities (notably *Research, Policy Foresight and Industry*) under the 'Dynamic Roadmapping' framework. This integrating activity is driven by the two activities of *'Co-innovation Roadmapping'* and *'Innovation Monitoring'* as depicted in Figure 99. This first map is the gate-way to all the other maps and models.

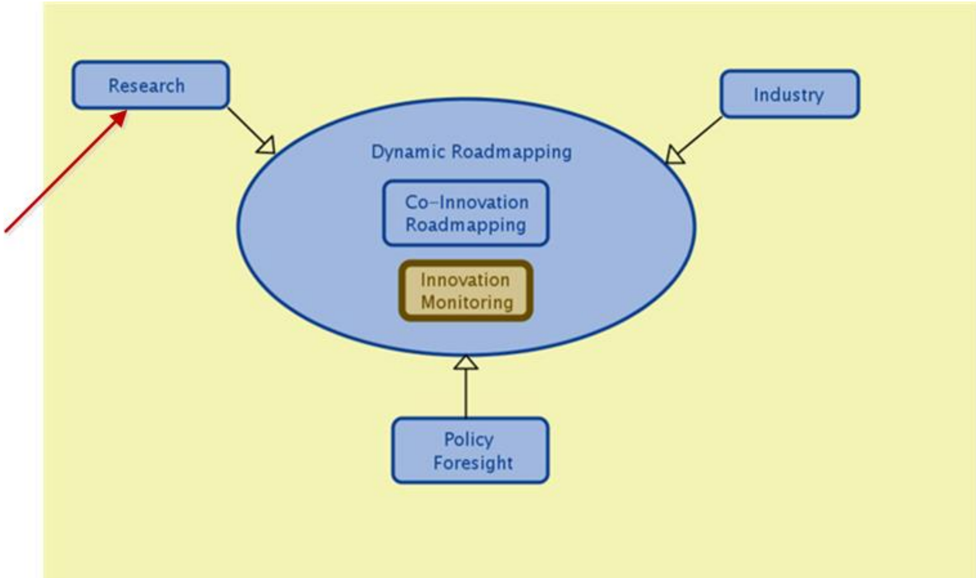


Figure 99. The TEL-Map start map shows the overall structure of the TEL-Map Roadmapping activities. Conzilla snapshot available at (Naeve & Kamtsiou 2013) *figure 10, p.5*

Figure 99 & 100 illustrates an example of how two different maps are linked together via their common concepts. The *TEL-Map start context map (see figure 99)* is linked to another context map called *'research roadmapping' (see figure 100)* via its concept *'research'*. In other words, by clicking on *'research'* concept in figure 99, another map called *'Research Roadmapping'* in figure 100 is appearing, which maps the research roadmapping activities in TEL. These activities can be further explored by accessing and navigating the maps behind these concepts. For example, in the 'Research Roadmapping' map (figure 100), we see the process *'external work'*, which refers the research roadmapping work of external communities. These communities are network of excellence and other associations which collaborated with the co-innovation group. At the same map, we see the '*Network of Excellence*' group, who includes the concept '*scenarios*'. By clicking on the *'scenarios'* concept in map (see figure 100), you can access the *'scenarios map'* behind this concept Figure 101. These are research scenarios derived by key TEL research projects and they that have been developed by the STELLAR Network of Excellence. They were linked to various concepts, and content, such as to TEL grand challenges, actual videos for each scenario, and to desired scenarios foresight activities of the 'EU schools co-innovation group'. In this way, someone can explore a concept in different context via these interlinked context maps.

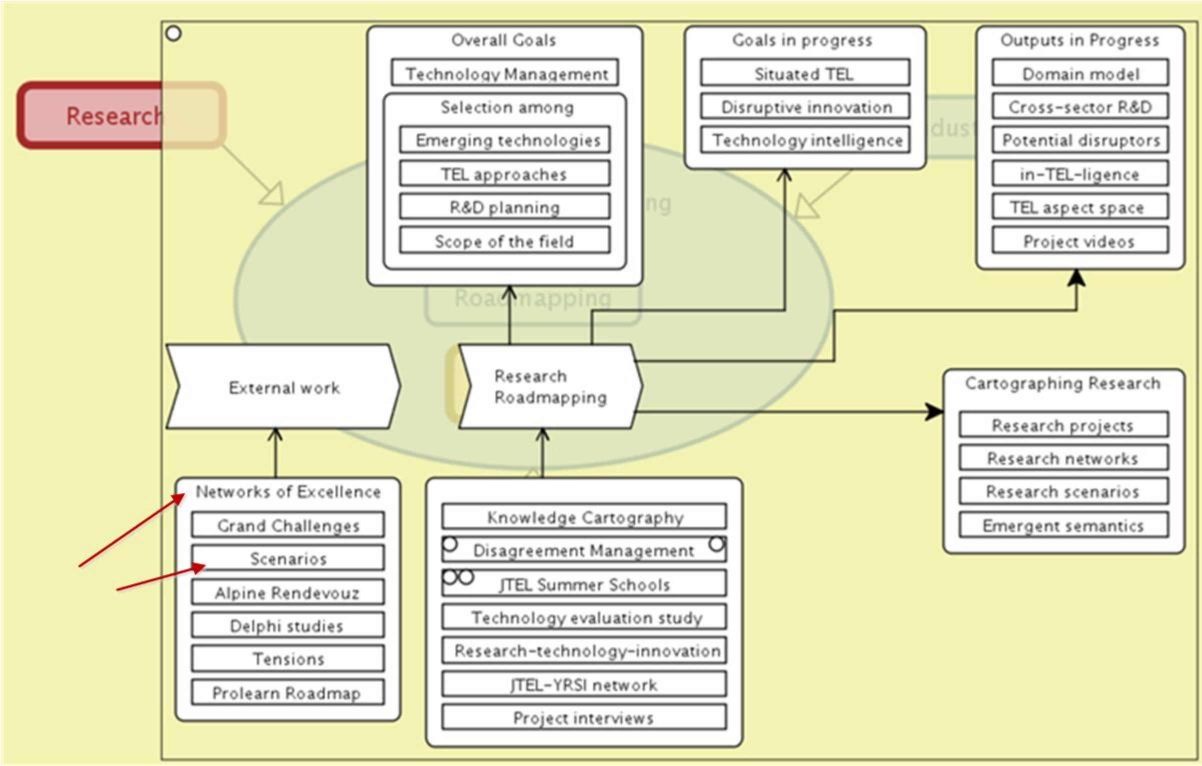


Figure 100. Connecting with the map on "Research Roadmapping". Based on Conzilla model available at (Naeve & Kamtsiou 2013) Figure 105, p. 19

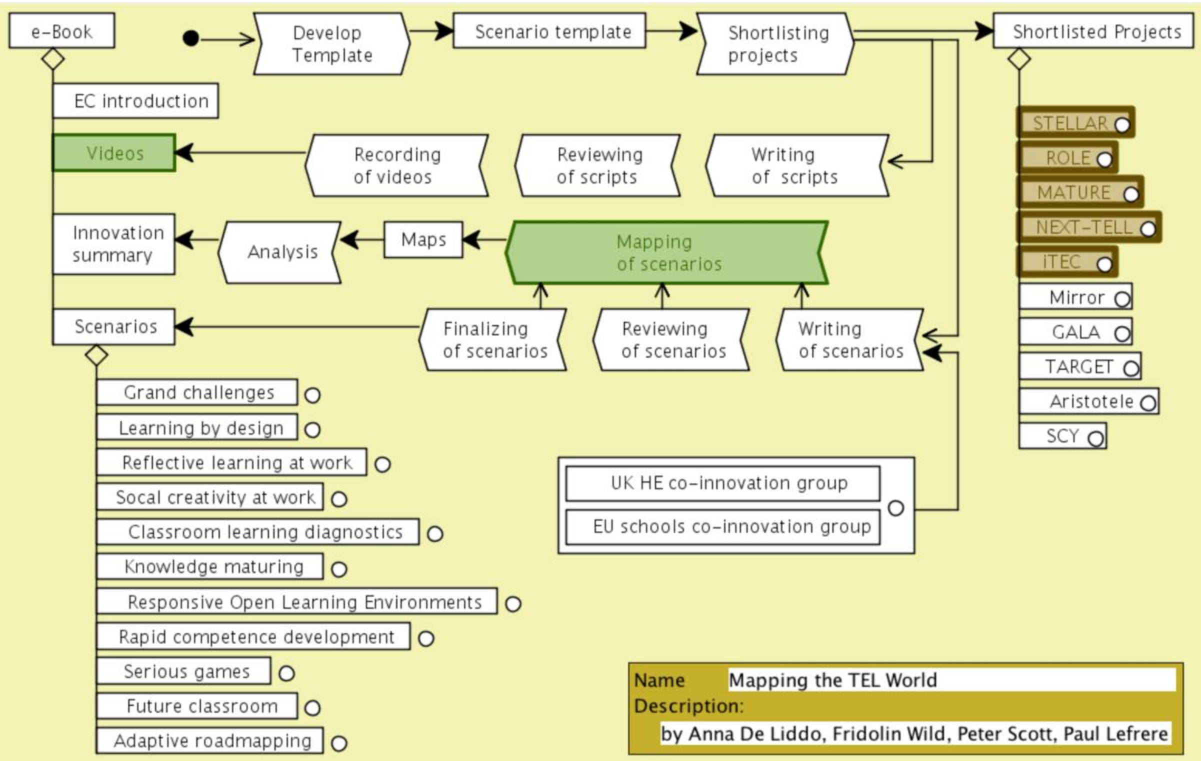


Figure 371. Scenarios map, which were developed by the STELLAR NOE, Mapping the TEL world. Conzilla model available at (Naeve & Kamtsiou 2013) figure 24, p. 20

As mentioned above, it was also possible to link web content to any concept, relationship, or context map. Figure 102 shows how content from Learning Frontiers portal was connected to the ‘blogosphere analysis. All the maps and metadata can be seen.

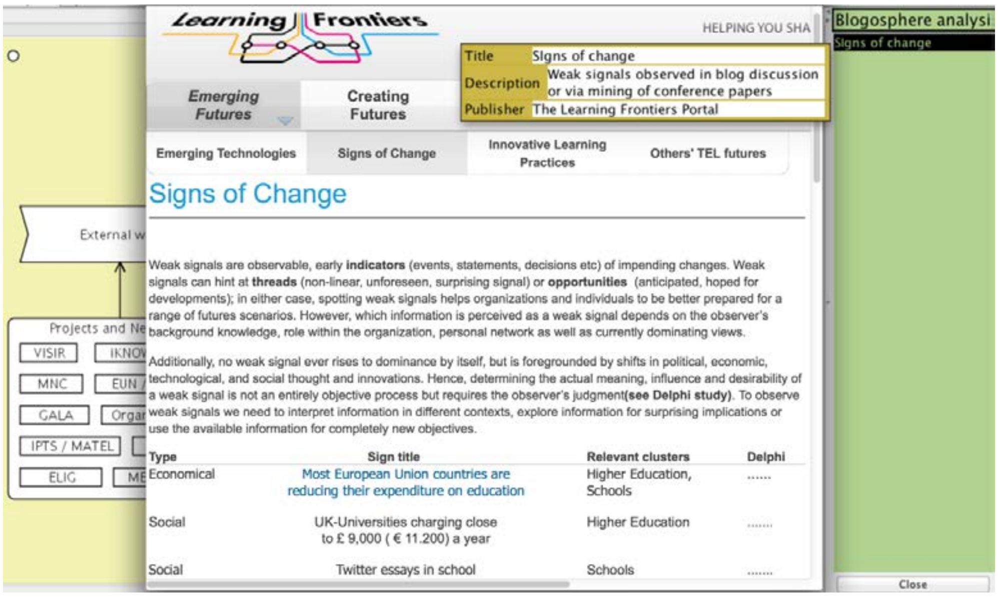


Figure 102. Double-clicking the item “Signs of change” in the content window to the right, directs the web browser to the corresponding part of the Learning Frontiers Portal. Conzilla model available at (Naeve & Kamtsiou 2013) *figure 48, p. 32.*

The co-innovation roadmaps were also modelled and presented in Conzilla browser and when possible, they were linked to other external related maps and content from the innovative communities. These are live electronic documents that can be used to represent and update the draft roadmaps. Figure 103 provide an example of how the co-innovation roadmap ‘assessment’ was modelled and presented as a Conzilla map.

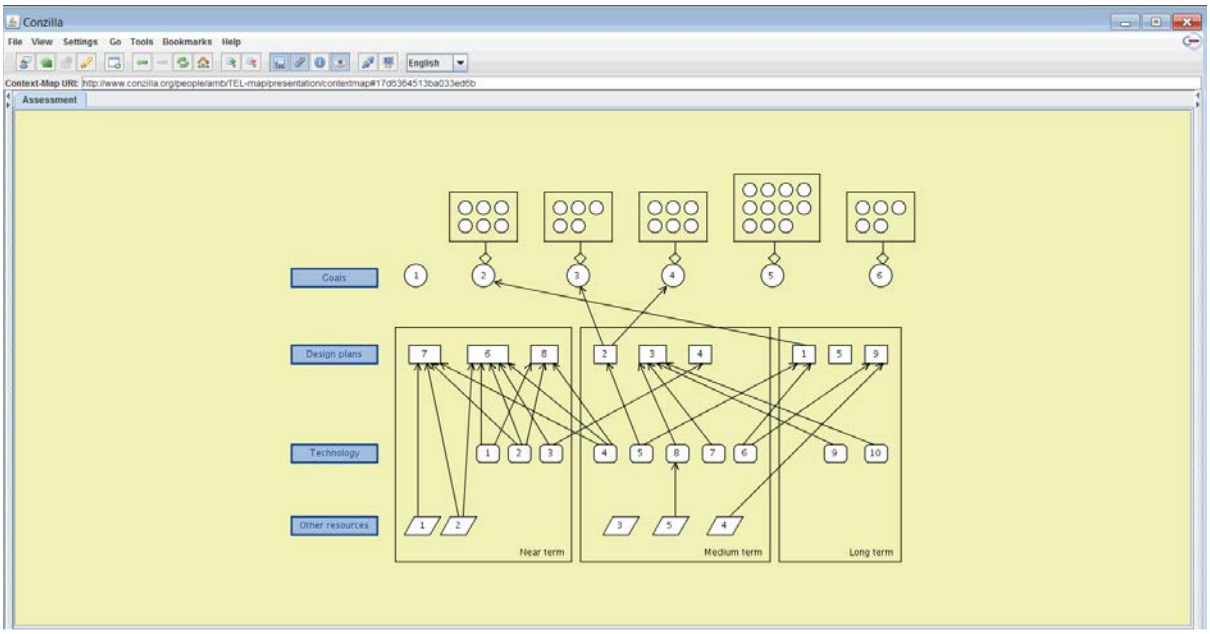


Figure 383. Conzilla model of assessment. Available at (Naeve & Kamtsiou 2013), Figure 212, p. 115 [*http://www.conzilla.org/people/amb/TEL-map/presentation/contextmap#17d6364513b9f640cd1*](http://www.conzilla.org/people/amb/TEL-map/presentation/contextmap#17d6364513b9f640cd1)

Figures 103, 104, 105 illustrate how the *'assessment roadmap'* map (figure 103) was linked to the *'TEL-Map process framework context map' (figure 104)* and to the specific process *'planning of initial/updated co-innovation roadmaps' (104).* When a concept appears in blue colour it means that another map is behind this concept. In this way the concepts could be linked to various contexts (maps). When a concept appears in brown (for example 'innovation monitoring' concept in start-up map (see Figure 99), it means that both other maps and web content is behind this concept).

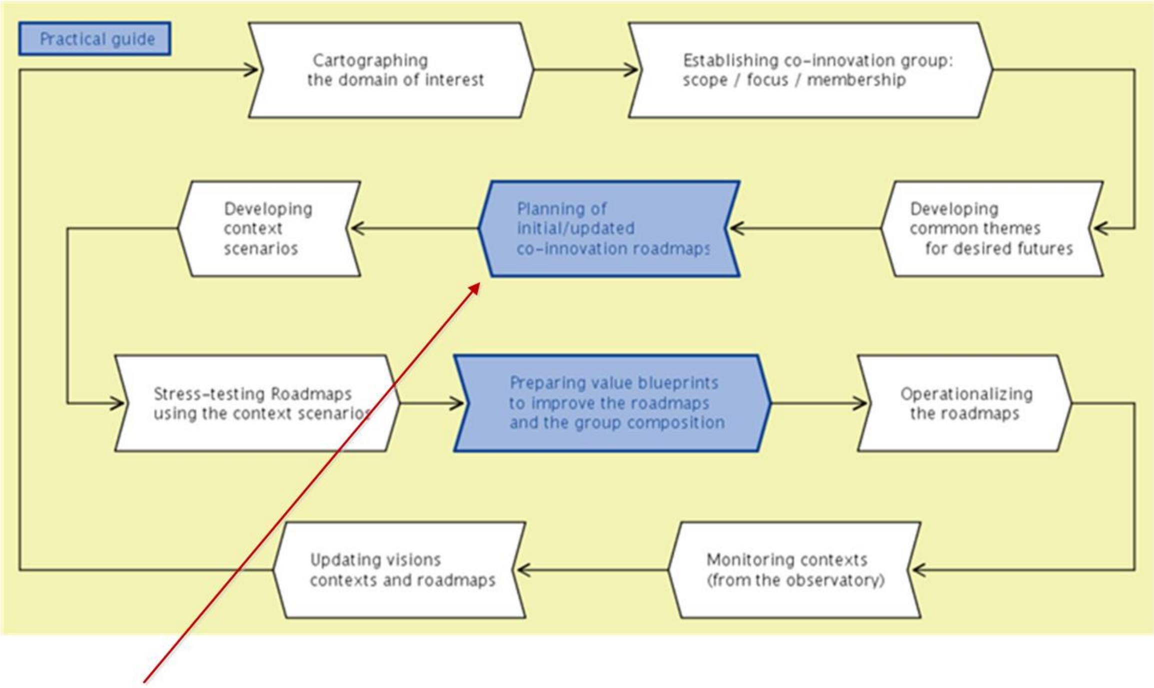


Figure 104. TEL-Map process framework Conzilla based context map. Available at (Naeve & Kamtsiou 2013) figure 3, p.6

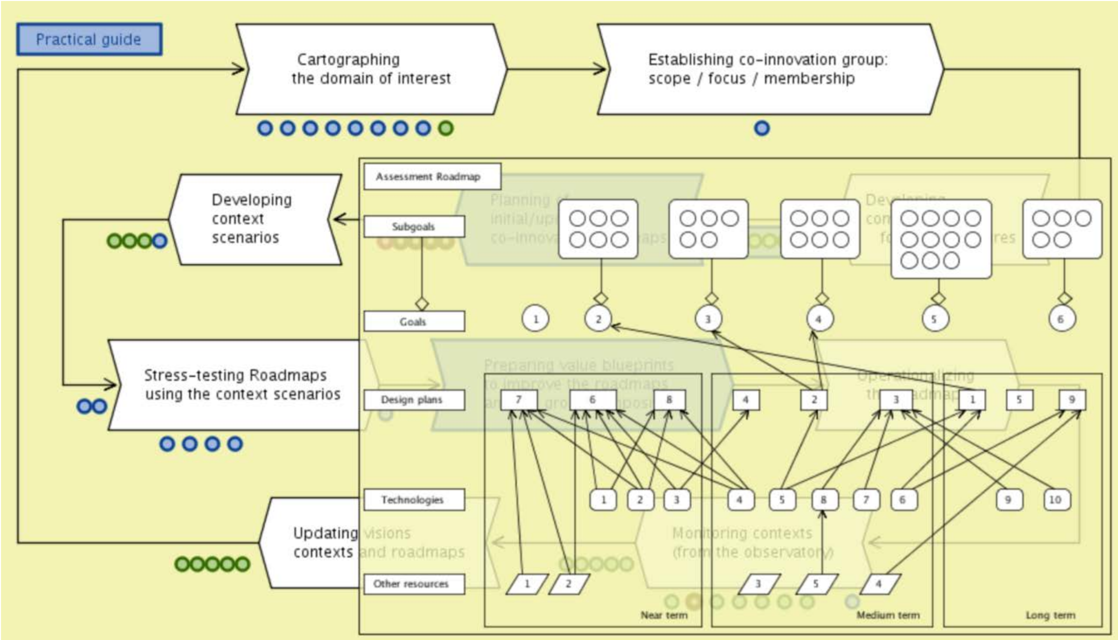


Figure 105: source: Conzilla based model. Clicking on this dot shows the connection with the Roadmap on Assessment. Available at (Naeve & Kamtsiou 2013) *Figure 211 p. 114*

By right clicking the mouse on the concept you can also navigate the different maps the specific concept linked to and appearing. See example below (See Figure 106):

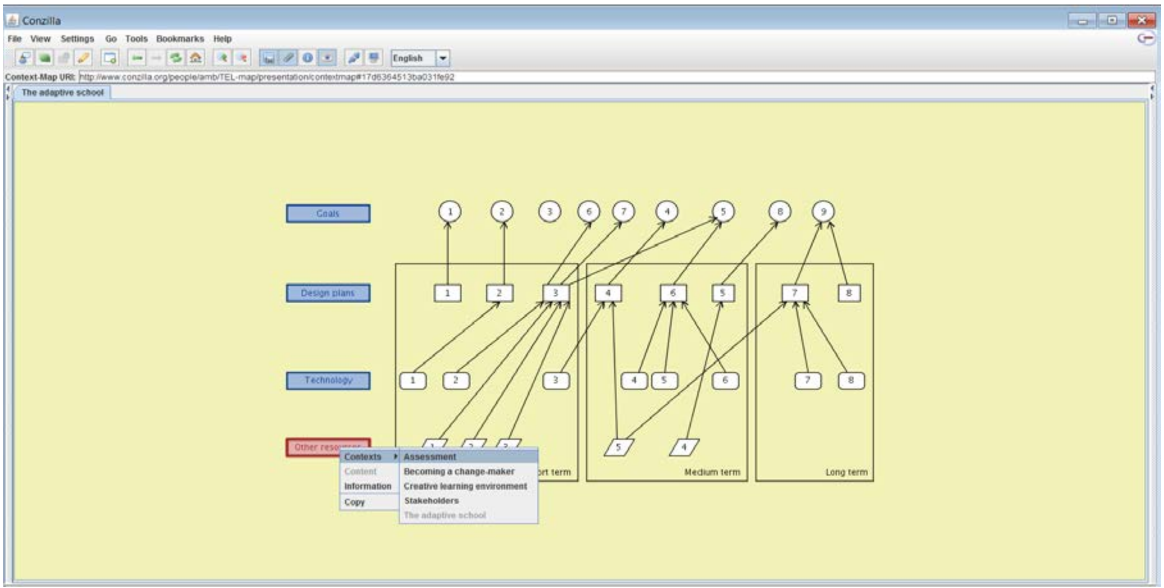


Figure 106: Conzilla based roadmap for theme adaptive school. Available at (Naeve & Kamtsiou 2013) *figure 259, p.139* http://www.conzilla.org/people/amb/TEL-map/presentation/contextmap#17d6364513ba031fe92*)*

Figure 107 shows the possibility of adding metadata in any concept or context map. It is also demonstrate how the co-innovation's maps were connected to the observatory intelligence. In this particular case, we see how the co-innovation '*assessment*' roadmap was connected to weak signals and their PESTLE analysis from the observatory. Figure 108 shows how by clicking on the link in the '*Assessment: Signals and Drivers link*' you can access the actual content of the weak signal.

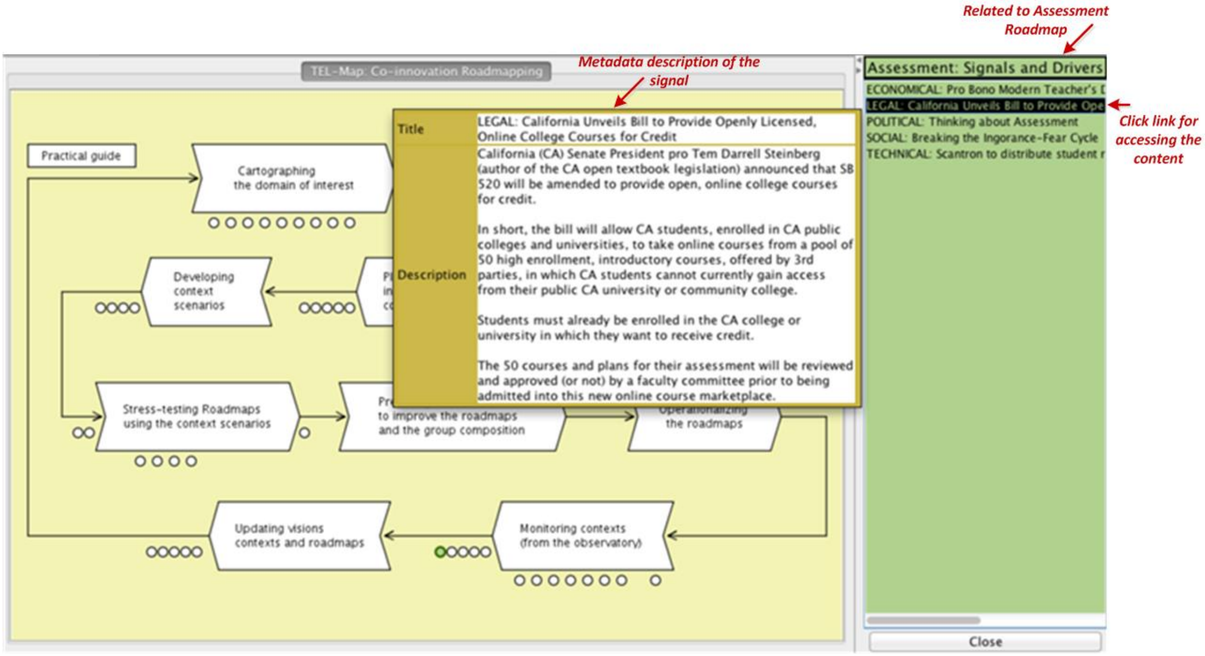


Figure 107. Showing the metadata of the LEGAL signal/driver: "California Unveils Bill to Provide Openly, Licensed, Online College Courses for Credit". available at (Naeve & Kamtsiou 2013), *figure 164, p.91*

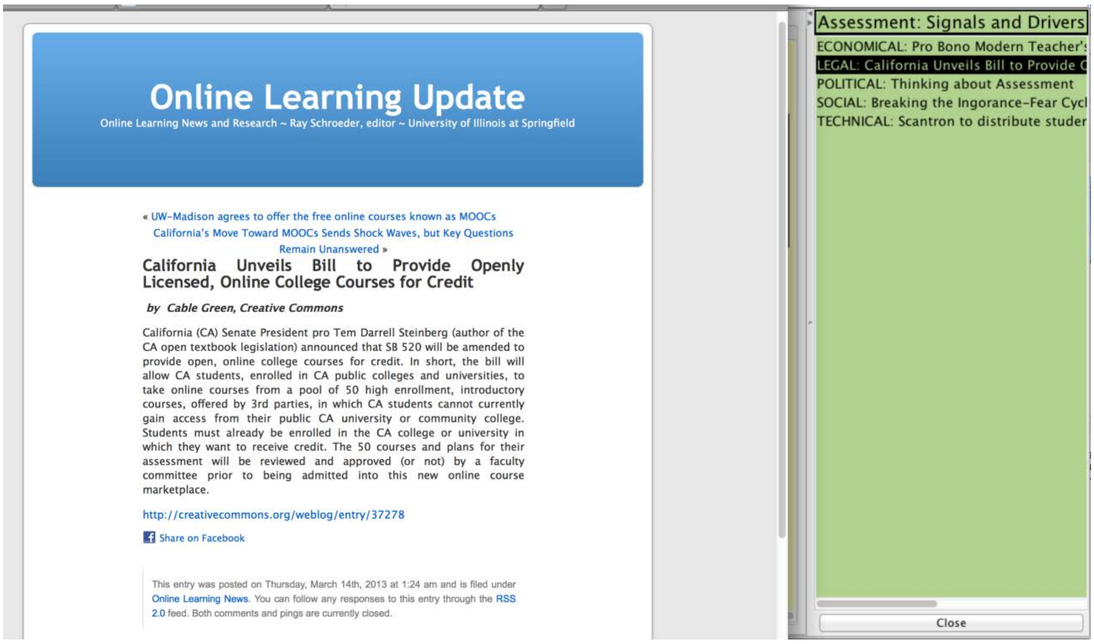


Figure 108: Opening the content of the LEGAL signal/driver."California Unveils Bill to Provide Openly, Licensed, Online College Courses for Credit" Available at (Naeve & Kamtsiou 2013), *Figure 165, p.91*

The Conzilla models of the co-innovation roadmaps were linked to the actual roadmap models that were created by the co-innovation group using the CmapTools application. See Figure 109.

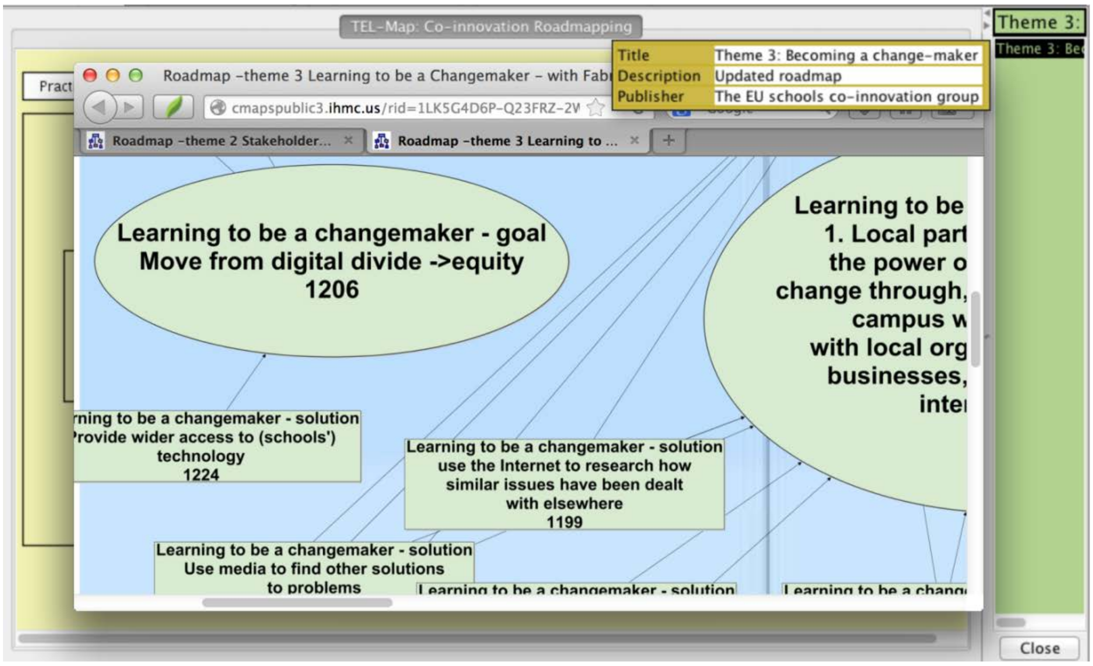


Figure 109. Becoming a change maker Roadmap Cmap mode. Connecting with the updated Roadmap on Becoming a change-maker at the Learning Frontiers Portal. Available (Naeve & Kamtsiou 2013) *figure 181, p.97.*

Confolio

The Confolio system[33] (a tool also developed by KTH partner), was used as a content management system for acquiring and sharing information among the TEL innovative communities. A Confolio system comprises of a number of interlinked electronic portfolios that can be owned and shared among different individuals and groups. These portfolios can support a large variety of content types varied from a) digital material, such as documents, films, pictures, slides, etc.; to b) information and opinions about this digital material; and c) information and opinions about non-digital material, such as persons, books, concepts, events, etc. Furthermore, Confolio was used as a semantic backend for the Learning Frontiers portal. A Confolio folder[34] was created dedicated to TEL-Map project in order to allow invited research projects, TEL researchers and other stakeholders to store documents, links, and ideas and collaborate with other portfolio owners by sharing information about the developed learning technology. Figure 110 shows part of the entry pages in Confolio for TEL-Map project.

33 www.confolio.org
34 http://telmap.confolio.org/apps/#view=default

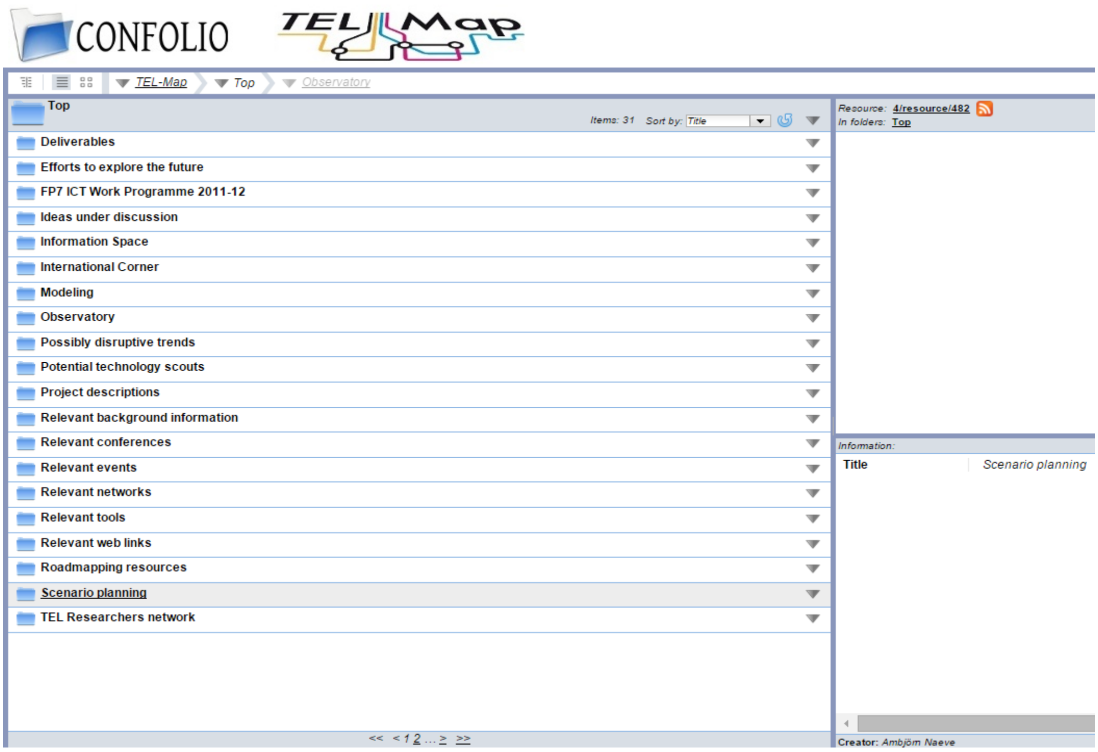


Figure 110. Telmap Confolio folder[35] snapshot

The Confolio system was integrated to both Conzilla browser and the Learning Frontiers Portal. The integrated services provided the possibility to connect different TEL innovative communities via their activities, networks and their goals. Based on a linked data approach, a network of TEL-experts (researchers, technologists, pedagogics, etc.) was created, which was possible to be semantically queried. For example: “Who is working with similar problems to mine but using different methods?” This approach also aimed to capture the long term impact of TEL communities and their projects. For this purpose, metadata entries were created in order to provide semantic links between the Confolio-based descriptions of a project (in terms of goals, obstacles, outcomes, etc.) as well as its relationships to other projects (in terms of predecessor, successor, related, etc.), actors (e.g. researcher, developer, industry player) and communities (e.g. project consortium). The results were also modelled and connected to conceptual maps in Conzilla (see Figures 111, 122). One of the aims of this work was to semantically map the different stakeholder communities in TEL. This means involving different stakeholder communities (such as EU projects) and (TEL providers) and (TEL users) to map out the "**activities**" of the community (in terms of how the community perceives what it is doing in TEL, what are the TEL issues that are trying to address, what approaches, solutions they are developing and why these specific approaches). This would help each participating stakeholder community to better understand and align its activities and strategies and find collaborators with similar interests in the domain. This approach was contributing to the domain cartography and to providing suggestions for the enhancement of the co-innovation group with missing experts, competencies, and other of the ARE-IN criteria needed to implement the roadmaps.

[35] http://telmap.confolio.org/apps/#context=4&entry=_top&view=default

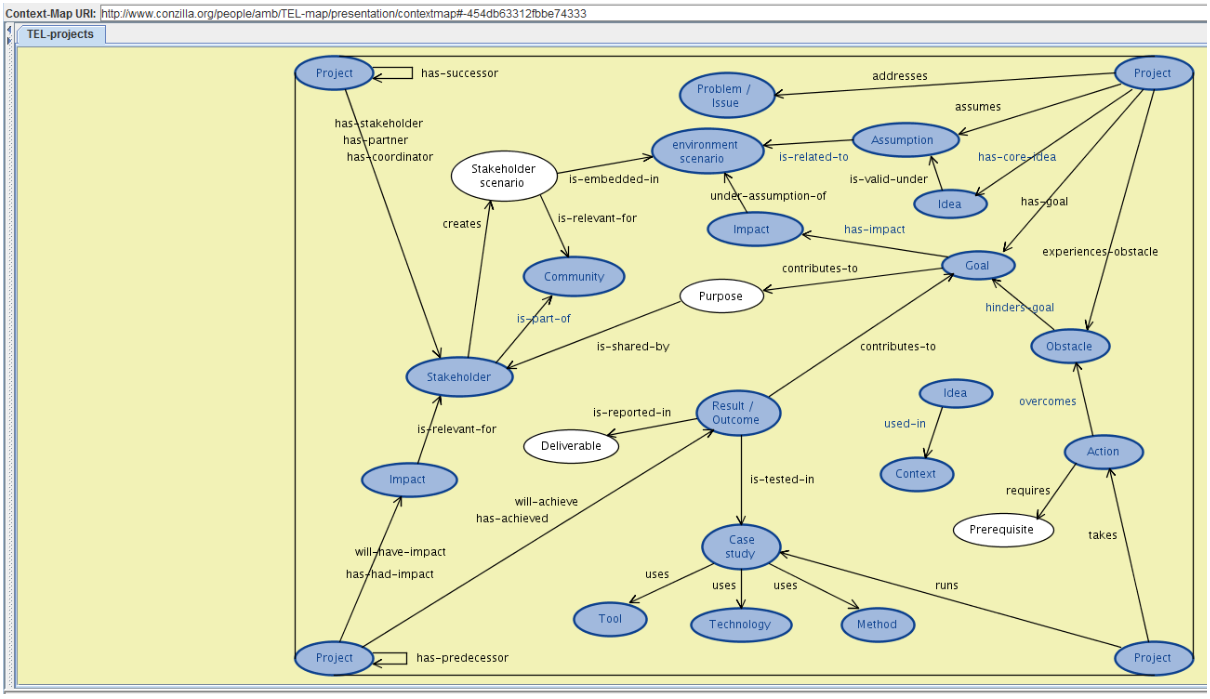


Figure 111. TEL projects modelled in Conzilla (snapshot)

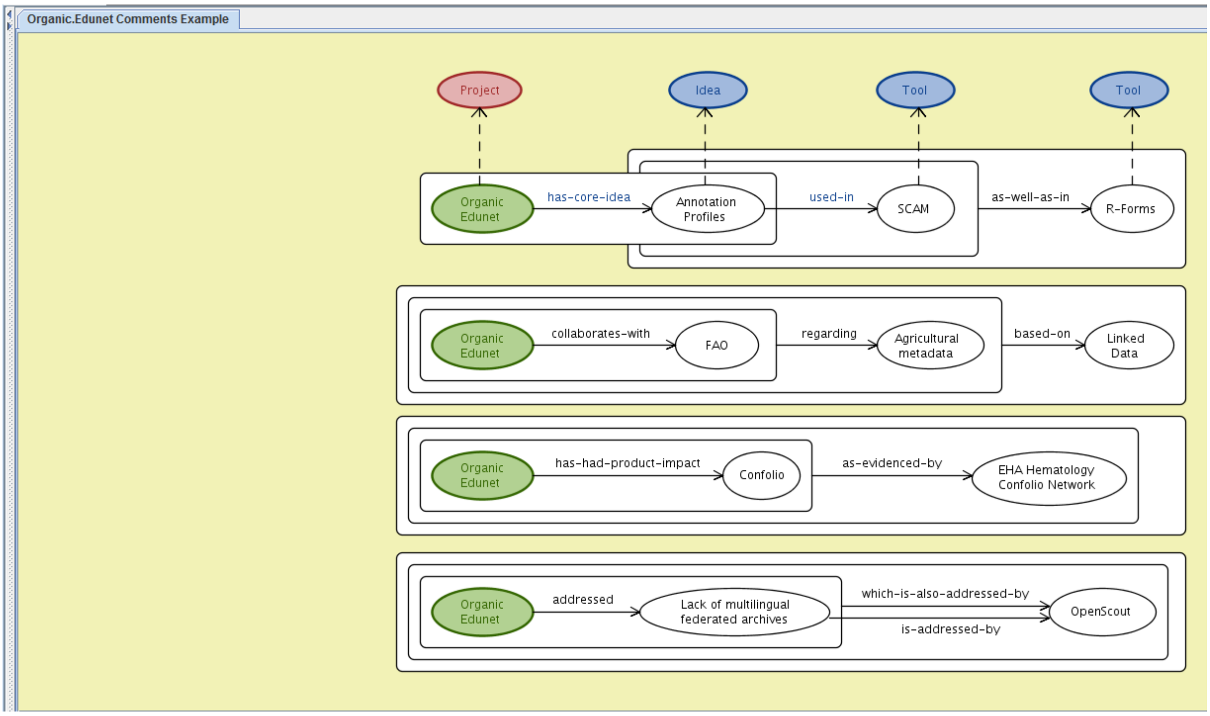


Figure 112: example of 'Organic Edunet' project model (snapshot)

Three similar metadata profiles specific for the Roadmapping in TEL-Map were used:

- Aspects of collaborative projects funded by the EU see screenshot in Figure 113, 114,115 & table14).

- Aspects of individual researchers' project such as PhD students (see list in page 269 and figure 117).

- Organisations (legal entities) that participate in collaborative projects funded by the EC (see figures 112, 116).

The first two metadata profiles were used in order to semantically connect and describe TEL projects and the projects' connections. The third metadata profile was use in order capture information about the connections (networks, organisations, communities, etc.) of the involved organisations. In addition to the metadata profiles that were created specifically for these purposes, existing vocabularies, properties and ontologies were also reused. For example, information was automatically captured from the individual EU projects website and the EU Cordis website, while others were added by surveys and interviews performed by the intelligent network (TEL-Map Observatory partners and the EA-TEL PhD students' community). The results were displayed in the "projects part in the portal" (Derntl et al. 2012), (Kamtsiou, Olivier, et al. 2013).

Cartography of research projects:

Interviews were carried out with all FP7 European research and development projects as well as with the projects of the Education and Culture Directorate of the Commission. The projects were asked to answer the following questions using table 14 below. The answers were semantically connected and presented in the project's portal.

Title	Name of the Project + Acronym
Is about	Short description of the main project vision, including the field/domain of TEL addressed (no more than 4 lines) …e.g. we are working within the area of… in order to contribute towards… (It should be similar to an "elevator pitch": a concise definition of your project as value proposition or unique selling point.
Keywords	Associated with the project
CORDIS	*The information in this tab was fed automatically from Cordis website.* Title, Abbreviation, Abstract, Contract number, Coordinator, Partner, Funded by, Funding, Funding scheme
CONTEXT	*(Where and within which areas is your project working?)*
Stakeholder	Who benefits from our project… is interested, affected or influenced… and why?
is related to	TEL concepts, areas, domains, what it is bound by? Which specific parts of TEL are you addressing?
Supported by (is based on)	What are the main ideas that are behind the approach of your project?
Contradicted by (is in conflict with)	What other approaches are there to the same problems based on different assumptions? (this is a question that is expected to be answered by people outside the project as comments so it is OK to omit it here)
Collaborator	Collaborative opportunities: we could use help with….from… people/groups/organizations that are good at…. in order to achieve our goals What are my weaknesses, from whom could I use help in order to achieve the project goals?
Predecessor	Other finished projects that have been related to the current project (our project has been

	based on/used the results of….)
Successor	Projects that have been started as a result of this project (these projects… have been using, based on our results…)
ASSUMPTIONS	*We are contributing…focusing on… because we assume… under the conditions/scenarios….*
Is related to (link)	What are the main assumptions you are making in order to achieve the results in the project – what are you taking for granted?
idea	remove from template since already addressed above (don't answer)
Innovation	What type of TEL related innovations are you developing? (e.g. products, services, content, technologies, process, practices, business models, etc.)
Influences	What external events, conditions, drivers would influence your assumptions?
GOALS	What are the goals of your project?
Contributes to	What purpose(s) are the goals of your project contributing to? What we are aiming to achieve… in order to contribute to…
Obstructed by	Problems/Obstacles/Challenges we must overcome in order to achieve our goals…
Influences	What events, conditions, drivers, factors may influences your goals?
IMPACTS	*How will the achievements of your project improve the TEL domain? We will improve… for the benefit of… (ongoing projects) we have improved for the benefit of…(finished projects)*
Outcome	List the outcomes and give short descriptions of their maturity (what is the state of readiness…proof of concept, early prototypes, functional prototypes, ready for use, best practices) has-outcome…. in the form of….
Impact	will-have-impact-on (expected impact)---- (on-going projects) has-impact-on (achieved impact)…. (finished projects) will-have-scientific-impact-on/ has-had-scientific-impact-on will-have-patent-impact-on /has-had-patent-impact-on will-have-product-impact-on /has-had-product-impact-on will-have-awareness-impact-on/has-had-awareness-impact-on will have impact in standards/contributed to standards… ….other…..
Used by	has-expected-use by (this question is already answered above so you can omit it here)
Influence	The effect of our impact will be increased if…. The effect of our impact will be diminished if…
Approach	*We are working according to…in order to achieve our goals*
Based on	Our approach is based on theory, model, ideas, …
Method	Methods and tools using in achieving our goals
Uses	Used technologies, tools, produces, services, standards
Description	

Table 14*: Projects metadata descriptions entries*

A more simplified version was also provided as an option with fewer questions.

- Title: the title of the project.
- Is about: a rough abstract explaining what the project is about.
- Keywords: keywords (tags) that describe the project best.
- Method: scientific methods applied within the project.
- Innovation: project results that can be considered innovative.
- Idea: the main idea behind the project.
- Outcome: the main outcome/goal of the project.
- Impact: the desired or achieved impact.

Figures 113, 114 and115, 116, 117 show some screenshots from Confolio and Learning Frontiers website related to the project's cartography activities.

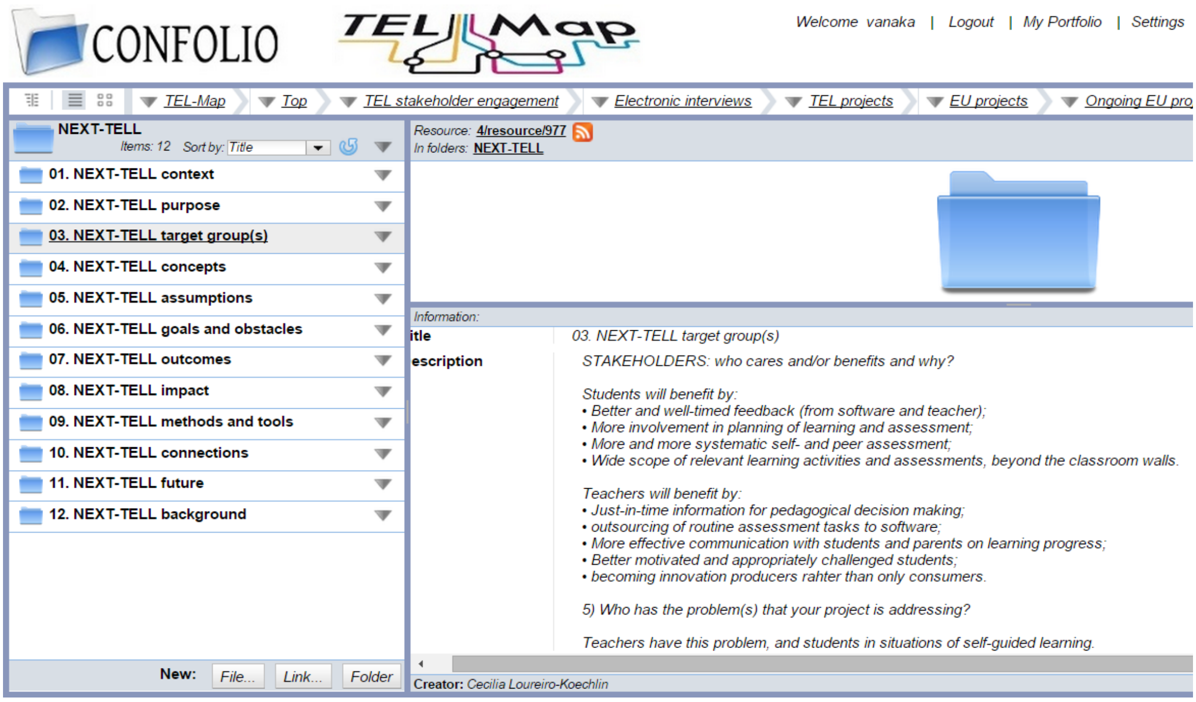


Figure 113. Example of metadata of electronic interviews for project Target in Confolio

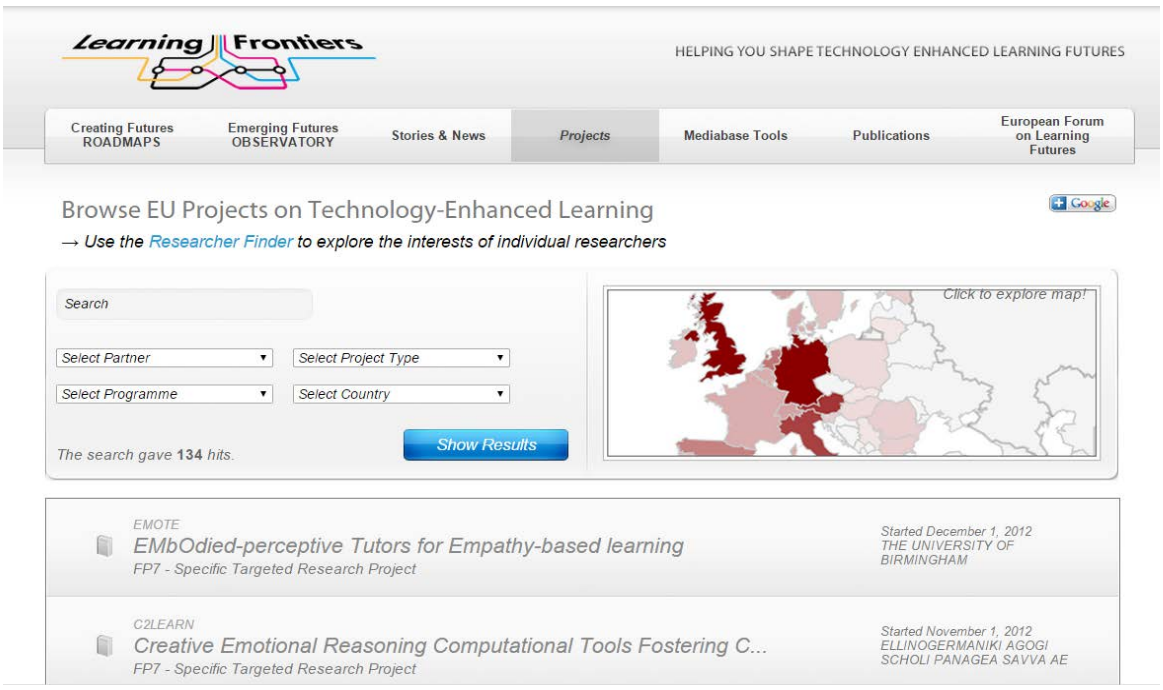
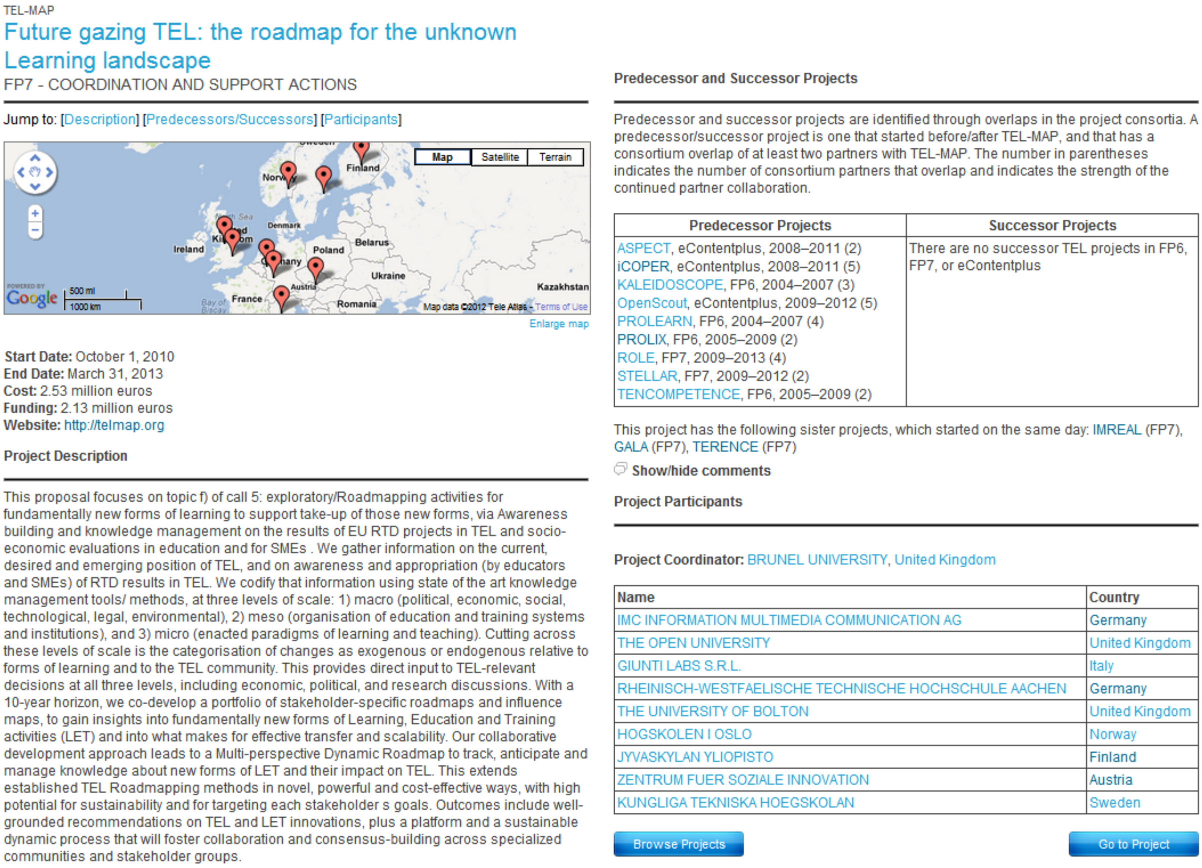


Figure 114. Projects at learning frontiers portal, front page snapshot


TEL-MAP

Future gazing TEL: the roadmap for the unknown Learning landscape

FP7 - COORDINATION AND SUPPORT ACTIONS

Jump to: [Description] [Predecessors/Successors] [Participants]

Enlarge map

Start Date: October 1, 2010
End Date: March 31, 2013
Cost: 2.53 million euros
Funding: 2.13 million euros
Website: http://telmap.org

Project Description

This proposal focuses on topic f) of call 5: exploratory/Roadmapping activities for fundamentally new forms of learning to support take-up of those new forms, via Awareness building and knowledge management on the results of EU RTD projects in TEL and socio-economic evaluations in education and for SMEs . We gather information on the current, desired and emerging position of TEL, and on awareness and appropriation (by educators and SMEs) of RTD results in TEL. We codify that information using state of the art knowledge management tools/ methods, at three levels of scale: 1) macro (political, economic, social, technological, legal, environmental), 2) meso (organisation of education and training systems and institutions), and 3) micro (enacted paradigms of learning and teaching). Cutting across these levels of scale is the categorisation of changes as exogenous or endogenous relative to forms of learning and to the TEL community. This provides direct input to TEL-relevant decisions at all three levels, including economic, political, and research discussions. With a 10-year horizon, we co-develop a portfolio of stakeholder-specific roadmaps and influence maps, to gain insights into fundamentally new forms of Learning, Education and Training activities (LET) and into what makes for effective transfer and scalability. Our collaborative development approach leads to a Multi-perspective Dynamic Roadmap to track, anticipate and manage knowledge about new forms of LET and their impact on TEL. This extends established TEL Roadmapping methods in novel, powerful and cost-effective ways, with high potential for sustainability and for targeting each stakeholder s goals. Outcomes include well-grounded recommendations on TEL and LET innovations, plus a platform and a sustainable dynamic process that will foster collaboration and consensus-building across specialized communities and stakeholder groups.

Predecessor and Successor Projects

Predecessor and successor projects are identified through overlaps in the project consortia. A predecessor/successor project is one that started before/after TEL-MAP, and that has a consortium overlap of at least two partners with TEL-MAP. The number in parentheses indicates the number of consortium partners that overlap and indicates the strength of the continued partner collaboration.

Predecessor Projects	Successor Projects
ASPECT, eContentplus, 2008–2011 (2) iCOPER, eContentplus, 2008–2011 (5) KALEIDOSCOPE, FP6, 2004–2007 (3) OpenScout, eContentplus, 2009–2012 (5) PROLEARN, FP6, 2004–2007 (4) PROLIX, FP6, 2005–2009 (2) ROLE, FP7, 2009–2013 (4) STELLAR, FP7, 2009–2012 (2) TENCOMPETENCE, FP6, 2005–2009 (2)	There are no successor TEL projects in FP6, FP7, or eContentplus

This project has the following sister projects, which started on the same day: IMREAL (FP7), GALA (FP7), TERENCE (FP7)

Show/hide comments

Project Participants

Project Coordinator: BRUNEL UNIVERSITY, United Kingdom

Name	Country
IMC INFORMATION MULTIMEDIA COMMUNICATION AG	Germany
THE OPEN UNIVERSITY	United Kingdom
GIUNTI LABS S.R.L.	Italy
RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	Germany
THE UNIVERSITY OF BOLTON	United Kingdom
HOGSKOLEN I OSLO	Norway
JYVASKYLAN YLIOPISTO	Finland
ZENTRUM FUER SOZIALE INNOVATION	Austria
KUNGLIGA TEKNISKA HOEGSKOLAN	Sweden

Browse Projects

Go to Project

Figure 115. Interactive geographical heat map of aggregate project data, figure from (Derntl et al. 2012) *from Figure 5, p. 10*

Organisation

The metadata profile about organisations was extracted automatically from project information from CORDIS EU projects website. This profile was used in order to connect projects to organizations semantically. A separate space in the form of electronic interviews was also provided in Confolio. For example see figure 116. These more detailed profiles belonged to the organisations in the co-innovation network.

It included the following properties:

- Name
- CORDIS short name
- Type (same as in CORDIS)
- Keywords (used as tags)

Researchers and companies Annotation Profiles

Researchers (incl. PhD students) and other TEL experts could describe their individual projects using the following properties:

Contexts: *Where*, i.e., within what *areas* of TEL are you working?
Enablers: *What projects* and/or *institutions* are funding your work?
Problems: *Which problems/questions/issues* are you addressing?
Goals: *What* are you trying to achieve with respect to these problems/questions/issues?
Purpose: *Why* is it important to reach these goals?
Stakeholders: *Who* will benefit if you reach these goals?
Expected Impact: *Why* will they benefit, and *why* will this be important?
Challenges: *What* are the *obstacles* that are preventing you to reach these goals?
Actions: *How* (by what processes), are you planning *to meet* these challenges?
Theories: *Which theories* are you using or planning to use?
Methods: *Which methods* are you using or planning to use?
Experiments: *How* (case-studies/use-cases/…) are you *gathering* empirical data?
Tools: *Which tools* are you using in your experiments?
Technologies: *Which* TEL-related *technologies* are you using?
Assumptions: *What assumptions* are you making?

The following Figure 116 shows an example of a profile of a company in confolio.

Figure 116: IMC metadata profiling in Confolio snapshot

The person (e.g. researcher, PhD student, Vendor, Publisher, teacher, etc.) could choose from already existing entries from controlled vocabularies or they could add new ones. Figure 117 shows how the pre-existing concepts of Stakeholder: 'Higher Educational Institutions', Method: 'Data mining', Theory: 'Constructivist theory' (See figure 117) were used. The existing vocabularies were developed with surveys, interviews with PhD students and TEL researchers at JTEL summer schools.

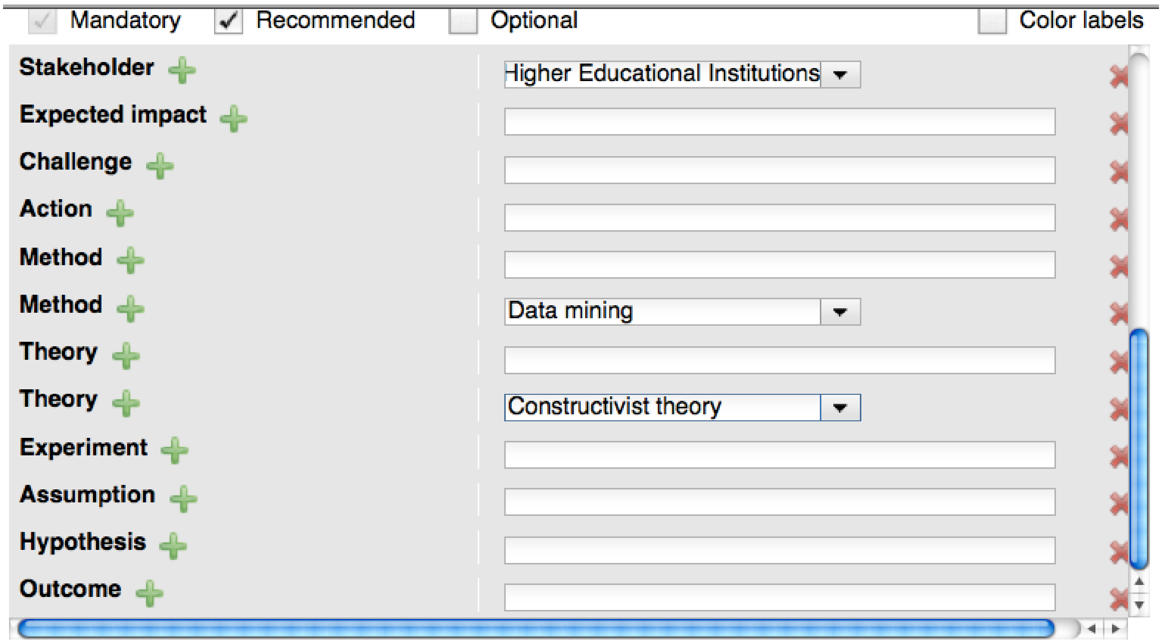


Figure 117. example of a personal profile entries

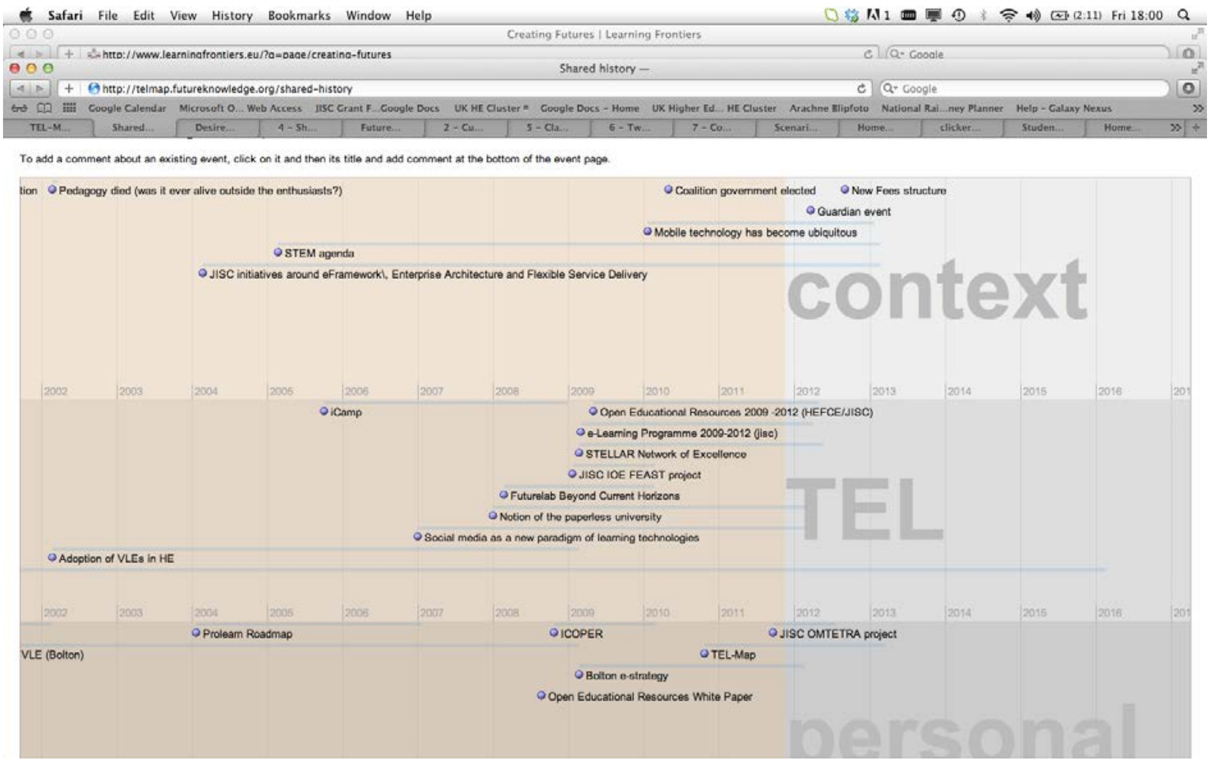


Figure 118. Shared history

Another tool that was used was the MIT's Simile Timeline, which enables a horizontally scrolling editable timeline (see figure 118). The co-innovation current and new members could use this tool to create shared histories about TEL. In the middle, they were adding past events as innovation milestones that could impact the desired future, then in the above Context layer, they added respective past events outside TEL domain and in the wider world that had an impact on TEL, and at the lower Personal layer, they were adding specific events from their personal histories. These information helped to prepare the co-innovation members to share histories prior workshop 1 (during the Search Conference event), and throughout the roadmapping exercise. It also helped the Cartography activities relate to TEL domain.

The Observatory network, the co-innovation group and other portal visitors, could comment on any concept presented at the portal. In this way, a monitoring of 'Communities voices' was performed on issues and strategic discussions. They could also search to find comments and discussions using free texts and by portal page. See figure

Figure 119: Searching for dialogues

A Researcher Finder tool (see example in figure 120) provided the co-innovation group and others a search mechanism to find stakeholders who had shared their profiles on Confolio. It allows filtering all researcher profiles on Confolio based on their Context (describes the focus of research), Stakeholder (the researchers profession, role or interests), Method (research methods used and applied by the researcher) and/or Theory (theories used and applied by the researcher).

Figure 120: Stakeholders Finder functionality at the portal.

6.4 Integration of research, industry and policy

In the 'Dynamic Roadmapping' framework, the different roadmapping communities are connected by shared issues through activities via a co-innovation roadmapping group and its observatory group. The information related to the roadmapping outputs of policy and research roadmaps are codified and fed as intelligence to the co-innovation group via the observatory. The observatory integrates *foresight (Policy roadmaps)* and *research (Research and industry roadmaps)* with the strategic planning of TEL stakeholders at their operational and innovation management plans *(co-innovation roadmaps)* (see Figure 121). For more detailed analysis related to synergetic relationships between Co-innovation, Research, Industry, Policy and learning practices roadmaps please see also section Chapter 3: Challenge C, & Chapter 7: section 7.3).

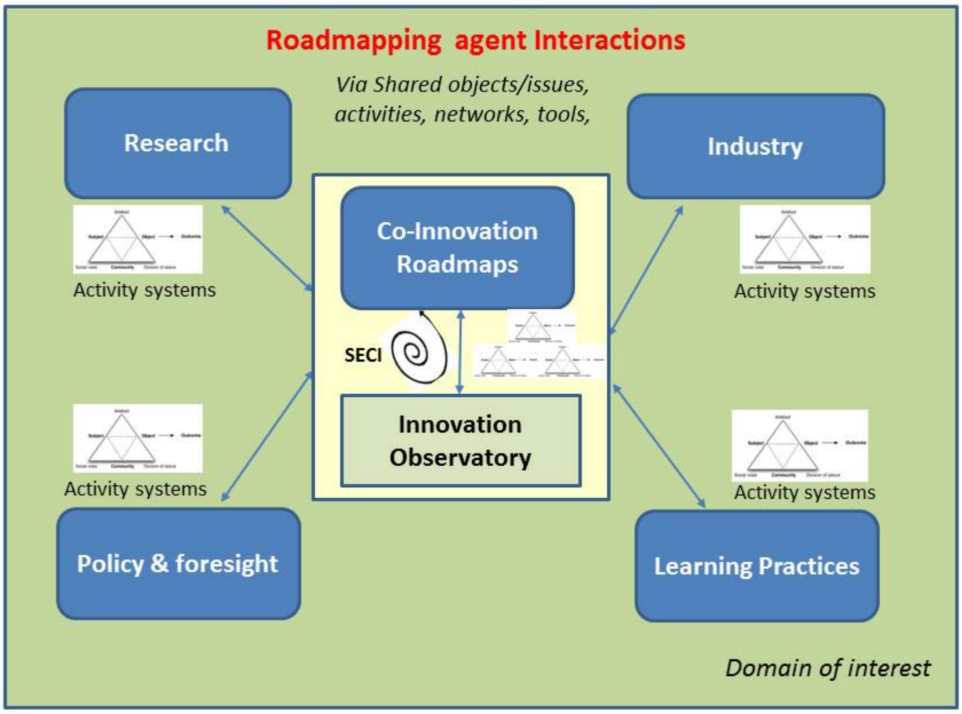


Figure 121. 'Dynamic Roadmapping' Model: Synergetic integration of different types of Roadmaps

This section summarise the activities in the different roadmapping methodologies and their integration by the observatory.

6.4.1 Research Roadmaps

This section reviews the main work carried on *Research Roadmaps*, which has been both supported by and informed the Co-Innovation and Policy Roadmaps. TEL research roadmaps are focused on TEL researchers and their communities (e.g. their organisations, standardisation bodies, networks of excellence, affiliations, etc.) as the main stakeholder types. Research roadmaps are focusing on developing the research capacities and looking at TEL grand challenges & their associated problems in connection to technology developments. Together with researchers, experts and academia, they aim first to identify the latest developments in TEL research and then, to develop research and development roadmaps that focus on the evolution and piloting applications of new and emerging technologies without a strong commercial product focus. This includes assessment and selection among emerging technologies and TEL approaches, but which may not be suitable for market deployment yet. It also includes investigation of other technologies, which are developed for TEL without a TEL focus but which could be used for TEL applications, The emphasis of these roadmaps is on organization of R&D planning and technological innovation management, as well as funding for basic research in case of longer term focused roadmaps. Such planning and innovation management is particularly challenging in the TEL domain, since R&D discussions and trials are characterized by:

- Rapid technological developments, which can quickly limit the relevance of specific elements of a roadmap.
- Growing demand for knowledge, while information and knowledge is in turn becomes rapidly outdated; This calls for short term results for R&D and which can lead to "packaged-TEL" forms of knowledge such as e-books, which may become rapidly outdated if the knowledge is too context-specific or device specific.
- The need for multidisciplinary competences from different fields (e.g. cognitive, pedagogical, education management, research, ICT, etc.)

A bottom up approach was foreseen for this kind of roadmapping development. The TEL PhD network together with the observatory intelligent network, STELLAR network of excellence, were mobilised to produce cartographies and maps of TEL research in Europe and model the different approaches taken by the research TEL projects. As demonstrated in section 6.3.4 above, the current research projects were analysed in order to map their outputs, innovations, approaches, technologies etc. This was done via electronic interviews with project participants. Each project then was allocated a confolio electronic space. The resulted maps were shared with the co-innovation group and among the TEL R&D communities, to identify distinct research areas and challenges in TEL, and also provide insights for research opportunities associated with the co-innovations roadmaps' targets. Towards this aim, there was close collaboration with, and take into account the results from, the STELLAR Network of Excellence, which was responsible for identifying grand research challenges, grand challenge problems, and research scenarios in TEL. Outputs include semantically interconnected maps of TEL research. The technical infrastructure of Conzilla, Confolio and learning frontiers portal was used as the basis for this mapping. A network was established of 20 TEL PhD-students as Community Modelling and Mapping Managers, who described their research semantically and related it to the activities and outcomes of the TEL R&D projects that are funding this research.

Primarily the Research Roadmapping activities have involved interaction with the TEL research community in several different ways.

- Collaboration with the STELLAR Network of Excellence, drawing on their Delphi studies and their Expert Workshops, and making use of their conclusions.

- Setting up a bottom-up process and work with the students and researchers in order to create a structured vocabulary for TEL that provides the basis on which to create the TEL domain cartography. Yearly workshops were run (2011 & 2012, 2013) at the EA-TEL Summer School for TEL PhD students and TEL researchers and engaged them in identifying new emerging areas of research and in projecting future research requirements.

- The Capturing the Voice methodology was used in order to enable topics to emerge and those interested in them to form discussion groups around them. The results were mapped at the Conzilla browser as the topic-human networks, showing who is working on what, in order to identify potential future collaborative groups. An in-depth survey and analysis of recent and current FP7 EU funded TEL projects was performed. The Observatory contacted coordinators or contact persons assigned by the projects in spring 2012. The following 22 FP7 TEL-projects replied to this request: Target, Mature, 80Days, GRAPPLE, idSPACE, LTfLL, COSPATIAL, xDELIA, ALICE, ARISTOTELE, ImREAL, GaLA, MIROR, MIRROR, SIREN, TERENCE, IntelLEO, Role, Next-Tell, STELLAR, iTEC, Metafora. Only three FP7 TEL-projects did not participate: eCUTE, SCY and DynaLearn. From this analysis, the Observatory intelligent network created both structured information about each project, as well as aggregated information about the projects taken as a group, which included among others: sector addressed, target adopters and technologies used.

- Review, comparison and synthesis of existing RTD on change factors affecting TEL (e.g. within TEL projects such as PROLEARN, ICOPER, STELLAR, ROLE, TARGET, CETIS projects, ELIG, FUTUREWORK, etc.). The full results of the study were made available under the link FP7 project survey results[36] within the research cluster in the Creating Futures tab of the Learning Frontiers portal[37]. From the survey result page, it was also possible to see the results for each project by linking to the Project Space of the Learning Frontier portal described in the previous section 6.3.4 (see figures 114 and 115) (Giorgini et al. 2013), (Kamtsiou, Olivier, et al. 2013).

- The Open University and the TEL-map project asked the top grant holders of European ICT funding to present a vision of what –from their perspective- is possible today, and to map out the key elements that would drive us to such likely and desired future of learning with technology. The visions presented had a strong disposition for impacting on all life aspects –in social, educational, technological and or economic

[36] http://www.learningfrontiers.eu/?q=content/surveys
[37] http://learningfrontiers.eu/?q=page/creating-futures

terms. A book was created, which presents the best of selection of innovative outcomes of a set of ten large-scale, collaborative projects funded by the European Commission in the 7th Framework Programme for Research and Development. The two network of excellence helped in integrating these various perspectives into a “big picture”, while at the same time shaping a vision for the longer term future and building the required capacity for getting there. The results were made available to the co-innovation group in the form of reports and eBook (Wild, Lefrere, Scott, et al. 2013), (Kamtsiou et al. 2012).

- Five major TEL conferences and a large number of blogs were analysed with the Observatory tools at Learning Frontiers platform. This analysis focused on capturing signals regarding the research directions in TEL research communities. The two data sets were: a) 2799 abstracts from ICALT, ECTEL, CAL, ICHL and ICWL TEL conferences from 2006 to 2012. b) 28116 blog posts related to education or training and technology from January 2009 to the end of October 2012 (Giorgini et al. 2013), (Wild, Lefrere, Millwood, et al. 2013), (Cooper & Voigt 2012),(Kamtsiou, Olivier, et al. 2013).

Figure 122 below shows the main processes and activities engaged in by the research roadmapping group in TEL-Map project. It shows the goals, the links with other research projects, the supporting research roadmapping methods and the research roadmapping outputs. As we see the key goal of these activities was to map and assess TEL research. Project and Networks were the intelligent sources which provided input in this process. This process was supported by TEL-Map methodologies and produced the cartography of TEL research as key output.

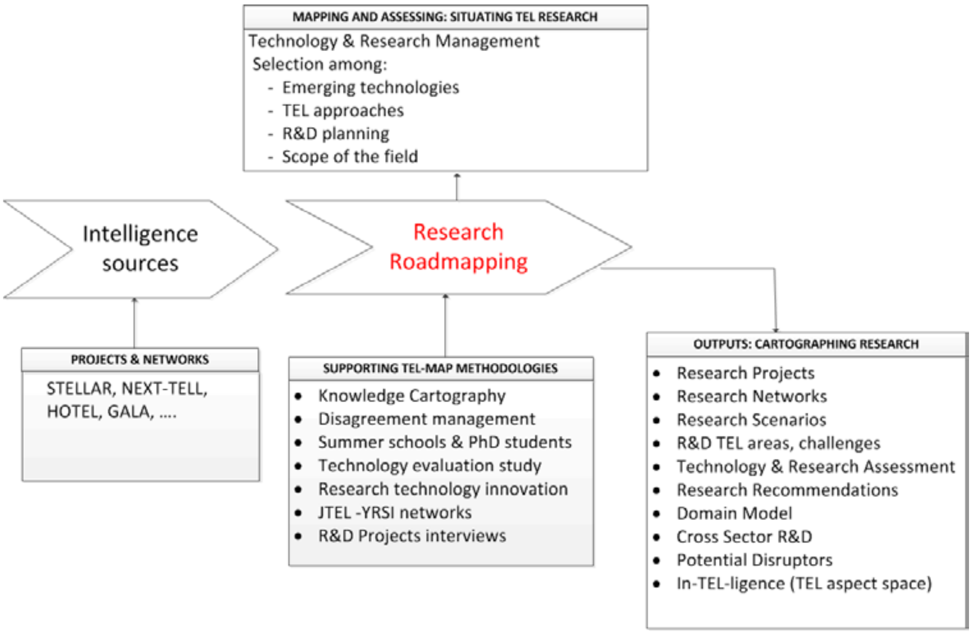


Figure 12239. TEL Research Roadmapping

6.4.2 Industry Roadmaps

Industry Roadmaps (state-of-play): In TEL sector, there are no established industry roadmaps, for example similar to SIA semiconductor roadmap (other than for developing eLearning standards), which is why the TEL-Map intelligent network has chosen to address the industry directly using interviews, surveys and workshops approaches.

Market intelligence via online consultations, interviews and analysis of market reports

This work lasted three months and was carried out by the observatory partners during f phases (Giorgini et al. 2013):

1. Online consultation and interviews
2. State of the art analysis
3. Gap Analysis – and industry involvement
4. Market relevance

Online consultation and interviews: state of play

This phase involved *online surveys and interviews* with key TEL providers at all major TEL fairs/exhibitions. During these consultations, 50 Experts from 11 countries have been asked to evaluate a) the importance of future societal and educational demands and challenges, b) the impact of technological developments, and c) the importance of future research themes. They were also asked to share their visions and the desirability and likelihood of becoming reality by 2020. This time period was then reduced to 5 years after consolation with the experts, who felt that the uncertainty in the economy and the fast technological changes made it impossible to make any longer term forecasts. They were also asked to identify drivers, which could affect TEL and the realisation of their visions. Full report was developed by observatory Gap Analysis report (Giorgini et al. 2013).

Analysis of Sate of the art

The intelligent network performed *Horizon scanning activities* which included a) analysis of key industry and market reports from analysts (e.g. Gartner, Doleitte, Accenture, Ovum and PwC), b) reports produced in education technology, by experts from the international community (e.g. New Media Consortium, Ambient Insight, Global Resources for Online Education), b) research and studies produced by the STELLAR - The European Network of Excellence in TEL , e) different whitepapers and articles on emerging learning technologies that were searched during a literature review. These activities identified technology trends and also they provided an assessment of technology readiness and time-to- adoption of the emerging technologies. The results were classified and grouped according to their time-to-adoption within the next five years.

Gap analysis

SWOT analysis was the main method used in gap analysis. This involved mapping Strengths and Weaknesses of the co-innovation desired futures (visions) and their technology needs against opportunities and threats. The visions of the Schools co-innovation group have been summarised and also analysed from technological perspective. This included opportunities that rose from “the voice of industry” workshop, which explored the relationships between stakeholders' needs (expressed in the co-innovation visions) and market solutions & technologies. The Gap analysis report was submitted to the co-innovation group.

Industry workshop - Market relevance of co-innovation roadmaps

A dedicated workshop with key industry players, such as TEL vendors, software developers, publishers, was organised by the intelligent network in order to explore and communicate the relationships between the stakeholders’ needs (expressed in the co-innovation group's visions) and the solutions & technologies provided or planned to be provided by the industry. The goal was to map the innovation opportunities perceived by the industry to the co-innovation visions and identify potential technology gaps (see also analysis at section 6.5.3 workshop 3: industry perspectives). The innovation opportunities, and value propositions identified by the industry, are explanations of the visions in terms of the industry’s contribution to concrete future achievements. Industry players will support future change in schools’ sector, through seizing opportunities, which may or may not be apparent in the initial vision and strategic directions of any group. The industry’s value propositions to address these opportunities identify the main features of the solutions offered and the market drivers from the perspective of the stakeholders (customers). It also helped the co-innovation group to understand the performance capabilities of the industry offerings. It answers the question, what can the industry provide to the co-innovation group? It also included the potential benefits of the solutions. It helped the co-innovation group to evaluate the offerings, but also helped the vendors to identify gaps in the market. In addition, participants were asked to identify gaps between the desired futures described in the visions and today’s state of the art in the area and current practices. The focus of these workshops therefore, has been to generate ideas that are relevant to the market, and externalize and describe these ideas in a way that they are understood by all stakeholders.

The intelligent network also provided additional analysis related the market relevance of the co-innovation roadmaps for the school sector. They have provided specific recommendations to the co-innovation group on how to fill the gaps identified from the gap analysis, between the current state of TEL and the future targets identified in the co-innovation roadmaps in the short-, medium-, and long-terms. Business analyst input was screened for recommendations and estimates of business potential and time to market. The weak signals from the horizon scanning, weak signal analysis, gap analysis and Delphi processes from the observatory functions, were associated with the co-innovation’s visions and its significance was analysed. A PESTLE analysis was also exemplified the schools context and the respective context scenarios. Then, market recommendations for the co-innovation’s roadmaps were produced by the observatory in a form of a market relevance report. These recommendations were also directly placed in the co-innovation's CmapTools roadmap models for their review and updating. Finally, the eco-system maps in the form of blueprints that were produced from the co-innovation stakeholders were further analysed and validated by the observatory. The idea was to further expose missing factors and stakeholders that help/hinder progress of the solutions planned in the co-innovation roadmaps.

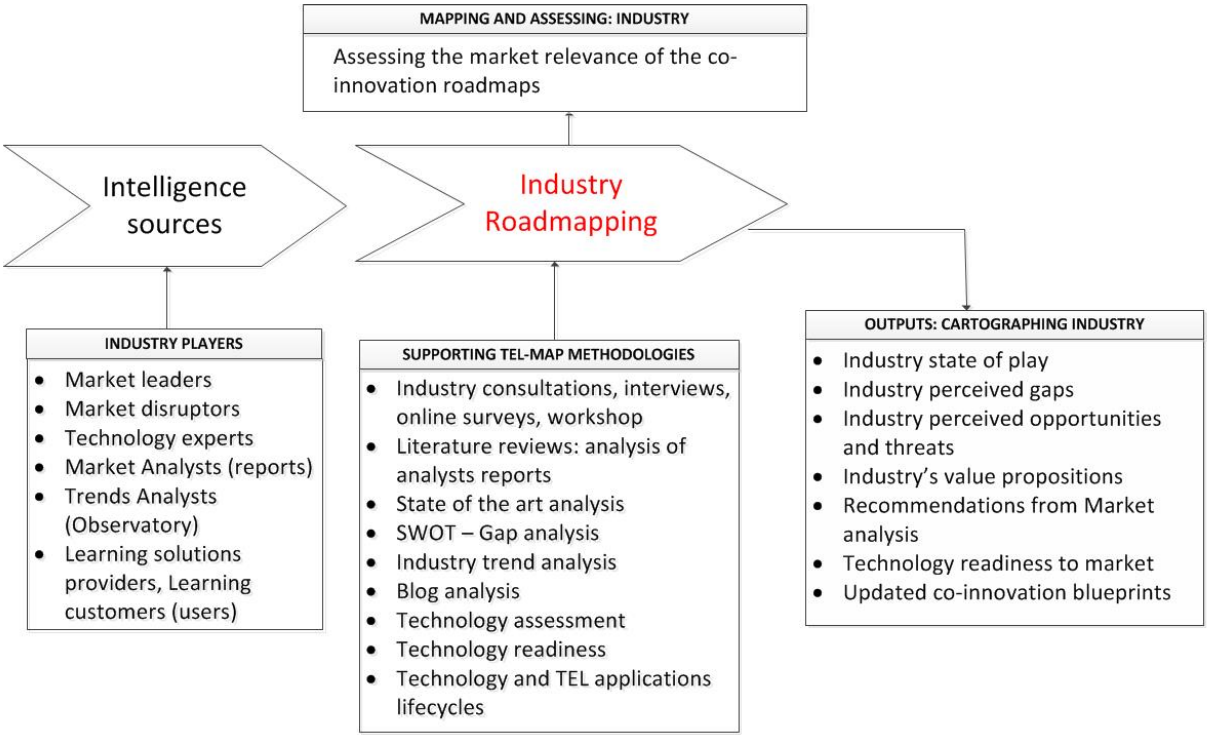


Figure 123: Examples of TEL-Map Industry related roadmapping activities

Outputs: State of Play in TEL, TEL state of the art, technology assessment, technology readiness, Identification of Social, Economic and technical drivers, SWOT analysis, Gap analysis, market relevance of co-innovation visions.

Figure123 depicts the industry roadmapping related activities (Wild, Lefrere, Millwood, et al. 2013), (Cooper & Voigt 2012).

6.4.3 Policy Foresight (Macro-Roadmaps)

Policy Foresight roadmapping activities provided recommendations to policy makers for developing TEL funding programmes. Such roadmaps have usually longer range planning and are mostly focused on sector levels. The focus of such stakeholders as funding bodies (e.g. EU TEL Unit) is to address and lift the most pressing barriers in TEL R&D and on other issues that might affect the strategic direction of long term planning in TEL and its adoption. They are usually strongly driven by societal, research, economic, and business factors. They focus on understanding the domains of change within the field, in different sectors and in different national, regional and European contexts. This kind of analysis includes describing where the tensions are, where the visions converge and where they diverse, what is the role of ICT and what are the barriers and obstacles that needed to be lifted. The results are disseminated to a wide audience of different stakeholders, as well as to the general public and they are used for policy debate and industry foresight applications. Usually they are great communication tools for discourse and disagreement management in the domain. They are used by politicians in order to develop a more shared public understanding and provide explanations about the policy and funding actions related to aspects of TEL, such as social demands, future targets, etc. as well as to justify public funding in R&D and prioritization in technologies development. The link between policy foresight (domains of change) and the co-innovation group (Stakeholders schools) is depicted in figure 124 bellow.

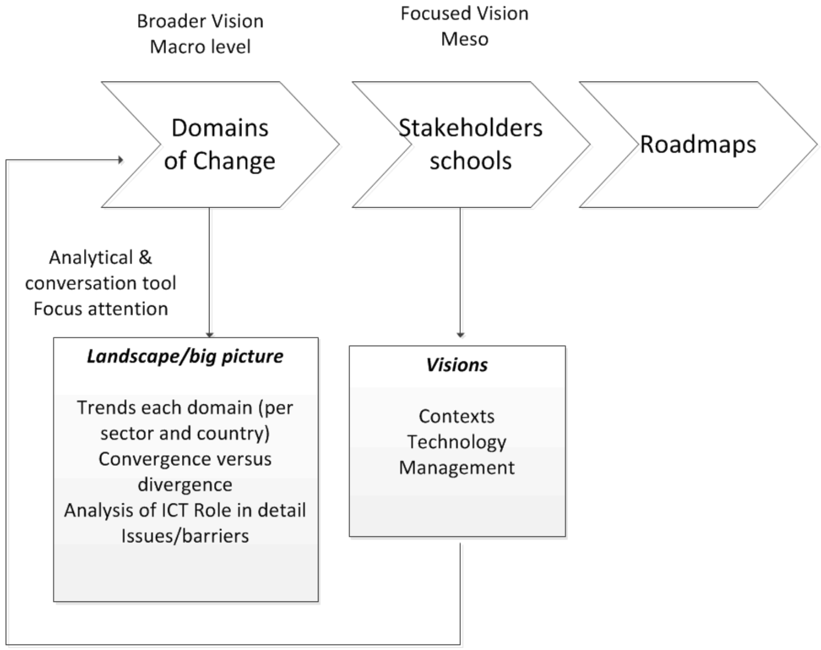


Figure 124. Policy Roadmapping in relation to co-innovation roadmaps

Policy foresight intelligence acted as radars in order to alert and inform the co-innovation group of opportunities and threats for their roadmaps, which were stemming from a PESTLE analysis and weak signal analysis. The Figure 125 below depicts the Policy foresight activities carried out by the TEL-Map observatory (and its intelligent network). Based on the initial drivers' analysis, and on additional foresight input provided by the co-innovation group after their first workshop, the intelligent network created *TEL context scenarios,* which were used in order to assess and stress-test the co-innovation roadmaps. This policy foresight intelligence was an ongoing process, which monitored the initial context scenarios and roadmaps. Some of the methods and tools used from the observatory intelligent network are described in the previous section 6.3.3 & 6.3.2. The following figure depicts the Policy foresight activities that took place in TEL-Map, the intelligent sources that were used, the aims of the activities and the outputs.

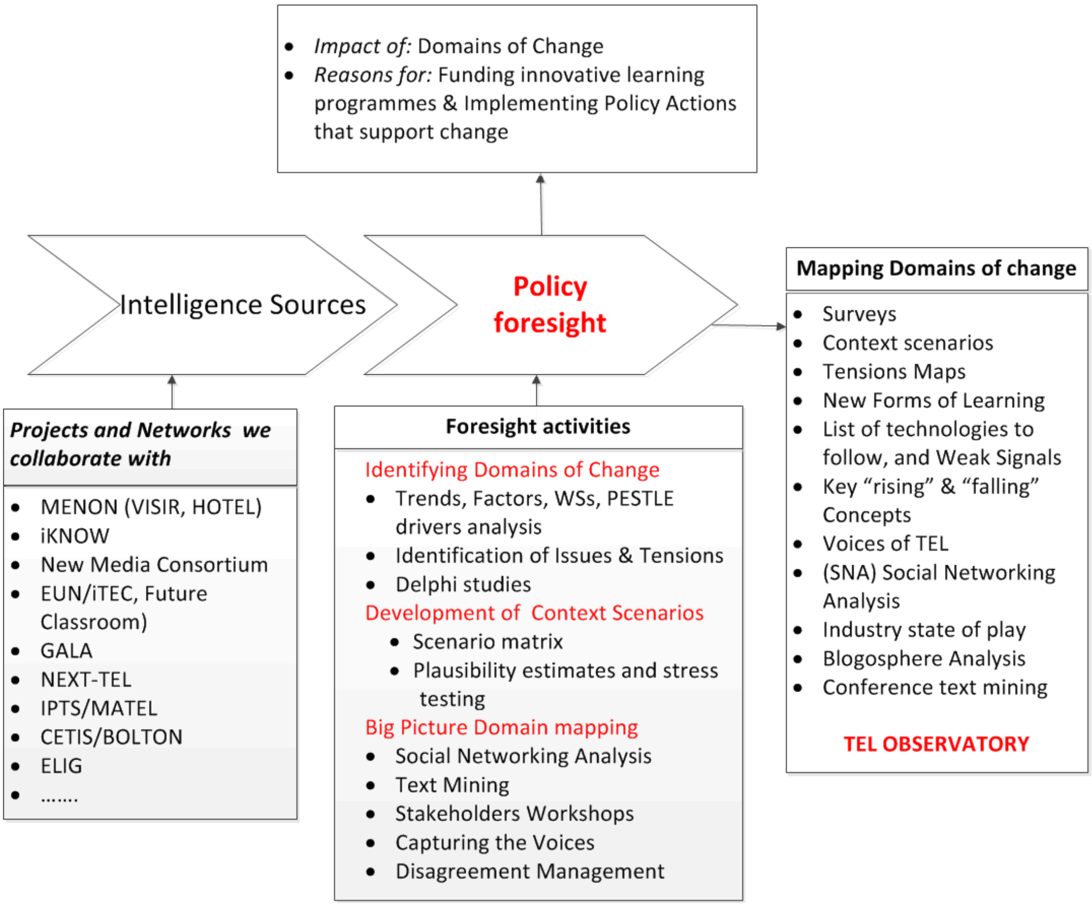


Figure 125. Examples of TEL-Map Policy Roadmapping related activities.

Monitoring TEL Domains of change:

As mentioned above, the existing and the emerging TEL aspects had to be analysed and continuously monitored. The co-innovation context scenarios (including their uncertainty drivers) and roadmaps provided a relevance filter to the observatory for which incoming data and observations to monitor (Voigt et al. 2012). For example, the contexts scenarios were the starting point for identifying signals that could affect the co-innovation roadmaps or indicate which of the context scenarios were closer to be materialized. The aim was to surface assumptions and key areas of uncertainty and to watch for signals or events that could impact the realization of the scenarios, and the directions of the roadmaps. At the same time, other signals that could influence the schools' education sector, but which were not yet under the radars of the co-innovation group or the observatory network were captured and analysed via *broader horizon* scanning activities (e.g. mining future technology blogs, participating in conferences and events, which their themes were on the boarder of TEL, and by having consultations with technology experts outside the TEL domain).

The following type of analysis was provided related to *weak signals*: a) *Signs* (reports of events that could affect TEL, school sector, and the co-innovation plans.); b) *Signals* (the significance of the Sign for the co-Innovation Group); c) *Significance* (the relevance of the event to co-Innovation Group's concerns).

A social Network Analysis (SNA) was also contacted using the observatory tools, which contributed to the domain cartography in terms of innovative communities' activities, their networks, areas of work, and their innovations. For example, looking at the published papers in TEL conferences, SNA revealed the most central authors in TEL, most frequent collaborations on TEL papers, most important TEL conferences and journals, development characteristics of authorship networks in TEL conferences. It also mapped the collaborations between TEL projects and consortia, Organizations; co-authorship of people and collaboration areas in similar topics; related blog topics and associated innovative communities, etc. For example SNA analysis showed that in FP6 EU research framework, the first (eight) projects together introduced 4,199 distinct collaboration connections among 157 organizations in the TEL landscape, in 2004 (Giorgini et al. 2013). Another interesting observation was that TEL blogs were referring to technology news and trends which were not particular TEL technologies, which reinforcing the claim that TEL depends on many technologies not originally developed for the education sector, making TEL roadmaps even more difficult to develop.

The observatory monitored this emerging reality using two types of sources: *a) exogenous sources* (sources created outside the TEL-Map networks, which were scanned via horizon scanning methods) and *b) Endogenous sources* (sources which were created by TEL-Map and its collaborating networks). A PESTLE analysis of these factors was provided by the observatory and was available to the co-innovation group via the learning frontiers 'Emerging Futures' web spaces (i.e., Emerging Technologies, Signs of Change, Future Content, Innovative learning), in weak signal analysis Observatory reports (Cooper, Voigt, et al. 2011), (Cooper & Voigt 2012), (Voigt et al. 2012), and via direct links to the co-innovation's CmapTools roadmaps.

- ***Exogenous sources included:***
    - Conference abstracts and conference papers. These types of content were then mapped to authors using information from DBLP (computer science bibliography database) and the AERCS database (the Academic Event Recommender system for Computer Scientists at RWTH Aachen[38].
    - TEL Blogs monitored by the Mediabase (via its crawl and indexed functions).
    - Tel research projects and their communities.
    - Policy reports, TEL foresight documents and roadmaps
    - Collaboration with other projects and networks. For example, VISIR Project was working on policy roadmapping at the macro contextual levels. The project also collected 100 micro-level practices of the innovative classroom.

[38] http://bosch.informatik.rwth-aachen.de:5080/AERCS/

- ***Endogenous sources*** included observatory surveys, workshops, desktop research, co-innovation events, documents, roadmapping artefacts, input from our collaborating networks, etc.

Another differentiation was made between sources from people and sources from the digital recorded info space sources.

- ***People sources*** for signals included Interviews, Delphi Studies (real time), stakeholders' consultations, and consultations with other policy networks such as VISIR and HOTEL projects, European School Net.
- ***Digital Recorded sources*** included Academic Publications, Project Descriptions, Postings, Blogs, Reports, Deliverables, Tweets and Expert Profiles. These were provided by text analysis, SNA, a Delphi Study and consultation/ feedback events.

Figure 126 depicts the Policy foresight activities of capturing and analysing weak signals.

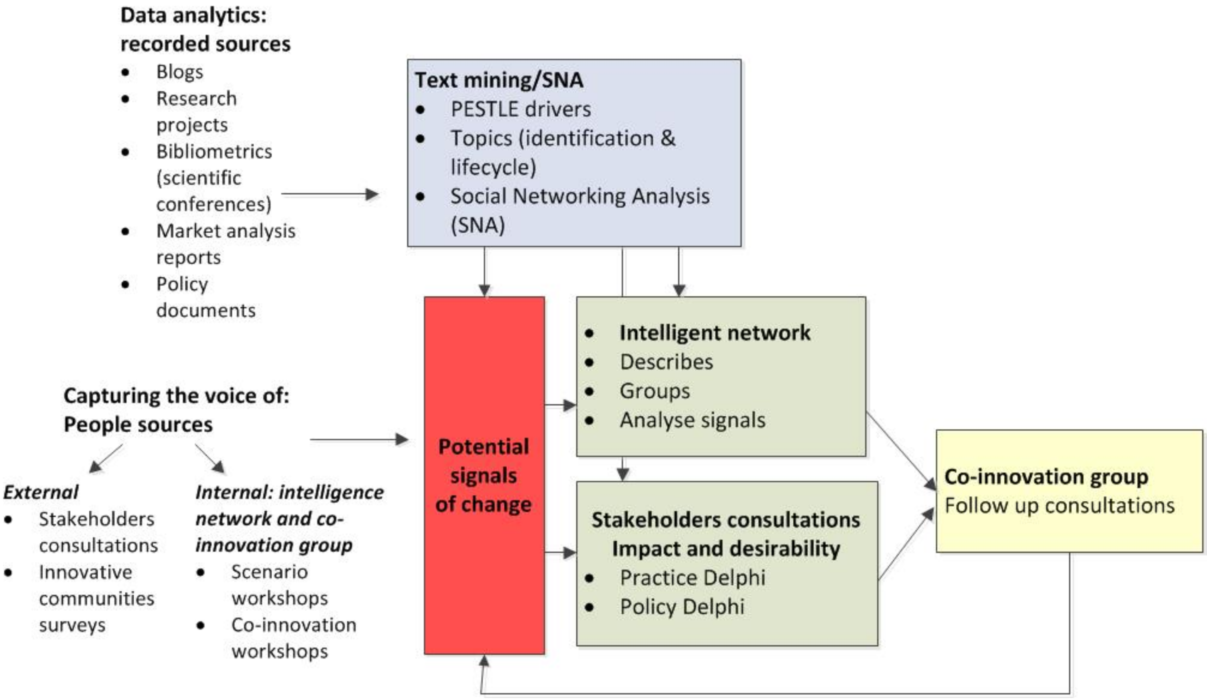


Figure 126. Capturing and analyzing weak signals

6.5 Implementing the 'Dynamic Roadmapping' co-innovation group workshops.

The co-innovation group achieved the development, stress-testing and updating of their roadmaps through *five (5) types of* workshops and *in-between* several other online meetings, virtual collaborations and consultations with the Observatory intelligence network. Figure 127 shows the five face-to-face workshops and the key steps involved in order to implement and monitor the roadmaps. It also depicts the virtual collaborations and the observatory activities performed in parallel (see also section 6.3, 6.4, 7.2.2, 7.3). Section 6.5 provides a description for each workshop, including the participants involved, the workshop's aims and objectives, the related templates used and the type of results. A more detailed analysis of challenges faced and lessons learned is discussed in Chapter 7.4.

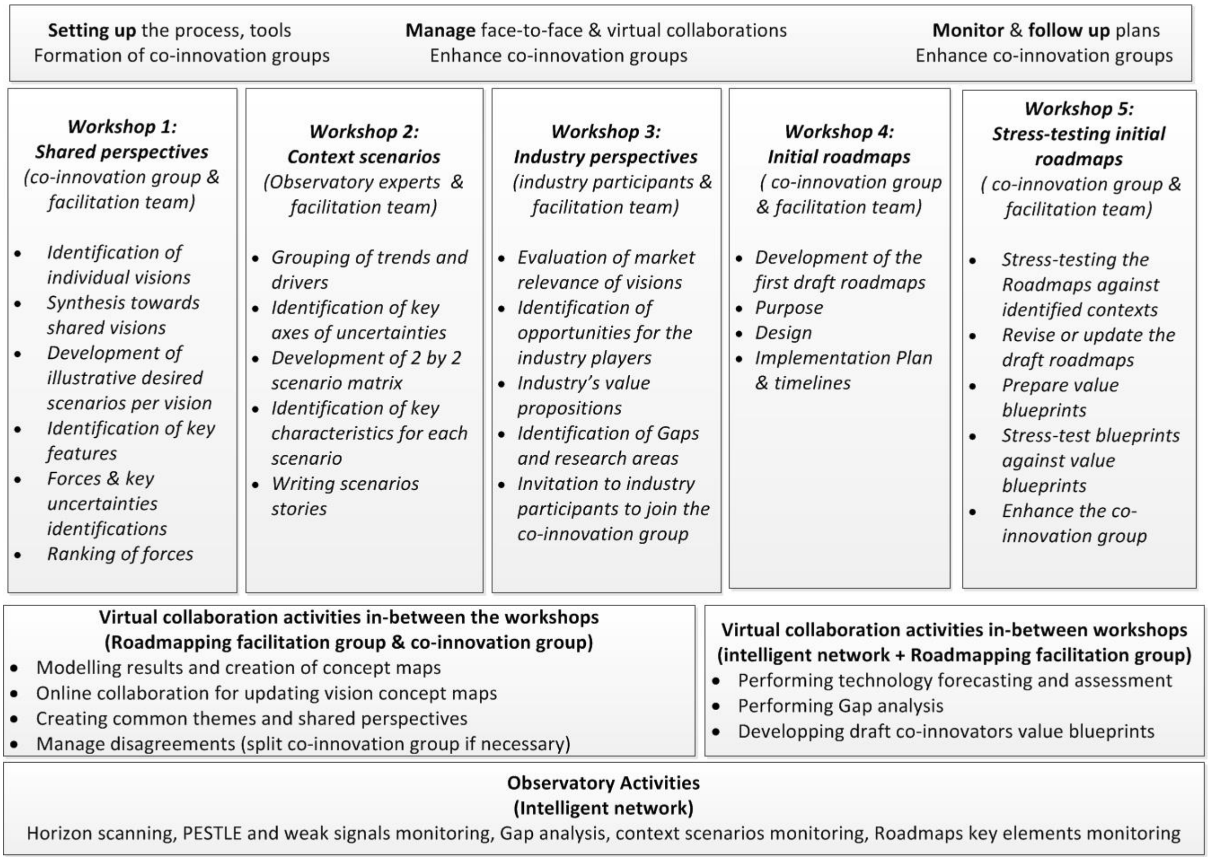


Figure 127. Co-innovation roadmaps: Implementation via five key workshops and online consultations

6.5.1 Workshop 1: Shared Perspectives

Participants: co-innovation members and facilitation roadmapping group.

The Aims of the workshop were to:

- Create the basis for the co-innovation group's shared desired futures around the *"changing schools to creative learning environments"* theme and express those using visions and illustrative scenarios.

- Start to map out the wider contexts in which the interrelated set of tasks for realising the visions will be played out.

- Rank the forces that might affect the vision's implementation in terms of importance and certainty.

- Set up the next steps for collaboration and explain tools to be used.

The co-innovation group first met in **Bologna on May 10th 2012** in order to develop their shared desired futures identify common perspectives and map out the contextual forces, trends and drivers, which might affect the realization of these desired futures. It was co-located with a major event, organised by the VISIR foresight network a day earlier, in order to be able to share stakeholders between the two projects and attract additional policy makers in the co-innovation group. During this meeting, six initial visions were identified, while it seemed that a shared vision was possible with variations in openness and control and different ways of bringing about change.

Create a common visionary framework as the basis for a shared desired future.

The steps for this activity were:

1. The co-innovation group developed six visions working in round tables, stimulated by the following proposal: "Imagine you are in the future, in a changed school, observing a creative class room with learning & teaching in the way you really like to see it". The ideas were recorded in the relevant tab in the group's Google Document workspace for each vision. An example of the Google document template is shown in the Figure 128 below.

2. Each table had a facilitator who was responsible to report on the groups' discussion on a common report session. They were also responsible for organising and coordinating the follow up online discussions after the workshop and to provide all versions and updates to the roadmapping facilitation team, and to the intelligence observatory network. The future search methodology for defining the desired future was applied.

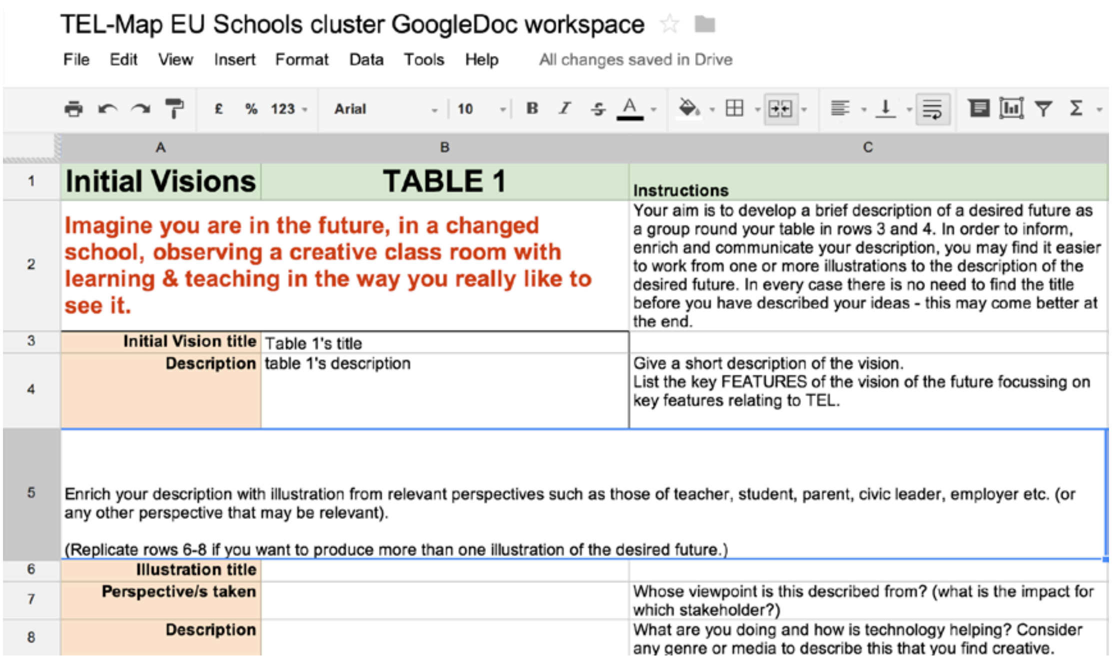


Figure 40. Google template for expressing school's visions

The 6 visions were presented in the Learning Frontiers portal in the creating roadmaps web space of the schools' co-innovation group[39] (Kamtsiou, Millwood, et al. 2013), (Naeve & Kamtsiou 2013).

An example of the vision ISP SOLVER description is provided below:

Vision 2: ISP SOLVER (Individualization, Socialization, Professionalization) - Shared, Open, Learning, Values, Environments and Recognition

Short description of the vision and list of key features: The main driver in this vision is to use education in order to "achieve balance between individualization, socialization, and professionalization". *Tension*: What's education for? Creativity (individual side) versus productivity (employer side)

Who are the 'clients'? Schools as "creative learning environments" seamlessly connected across school, home & communities:

Characteristics:

1. Increase creativity in the disciplines having open learning objectives.

2. Increase learning variation in terms of personalised learning paths/portfolios (leading to increased learner awareness of: purpose of education, strategies, and ways of demonstrating knowledge a skills.

3. Develop new forms of assessment methods: such as eportfolios/blogs, competencies mapping, to demonstrate their knowledge along with the current exams based assessment. Kids should be able to demonstrate learning, competences and skills acquired in a variety of contexts and types of actors such as to teachers, to peers, parents, and employers, etc.

4. Contextualize learning to everyday life of students to demonstrate the importance and value of education in person's life.

5. Provide new ways to engage and motivate learners: e.g., Gamification of things that we don't want to do as a motivation factor (gamified by whom? by learning designers/teachers/learners?).

6. New structures of schools open to the society, parents, researchers, local community. Including, the school as a physical place to be opened for other activities, as a space available to the local community (not open only in the mornings and closed for the rest of the day).

7. Making learning seamless (e.g. Self-directed Seamless Learning... Wong & Looi 2012 http://www.computer.org/csdl/proceedings/wmute/2012/4662/00/4662a001-abs...), Breaking down the boundaries between school, parents, teachers, employers,

[39] http://www.learningfrontiers.eu/?q=content/individual-visions-task-3-0

etc. via the use of technologies (e.g. a tablet, a social group could be a boundary breaker to link and elaborate what happened at school to home, peers etc.) transfer the same model to school - library, school - employers, school - companies e.g. Google learning, Microsoft Imagine Cup, Microsoft Partners in Learning programme, etc.

8. High quality learning and education should be public goods and free for the public (I want the best education and I want it for free - synergy with current initiative, such as Stanford's AI course and other MOOCs - reverse of this is I want the best students, not just those that live in this country, can afford to go to Stanford, etc.).

Illustrative scenario

The school is administrated by a board of multiple stakeholders' governance structure where the ministry is one of the voices. Learning objectives are reviewed every year by the local governance committee based on the local needs. A common core of learning objectives is defined and others are elected by the students. Different learning strategies are available to the kids while a special (as an education professional) helps the kids to choose what is best for them and their situations, also helping the kids to develop options that are available outside school. Learning is modular with not a fixed limit of time, but with varied pace. A wiki is formulated by different stakeholders trying to identify what is valued as learning and learning goals, without a need to be unified or reach consensus. Education experts including market places are working to assess and demonstrate different learning strategies and assessment for the learning opportunities. Tax incentives should be given to professionals and experts who are willing to contribute to the development of learning opportunities not just for the children, but for the whole community around the school (open idea). Kids move around schools for certain days and are able to freely share resources among different schools. The learners are able to demonstrate achievement of learning objectives to themselves, society, professional and academic world depending on what are aiming for: e.g., become entrepreneurs, master a concept of a skill, increase a competence level etc. Assessment could be a responsibility of stakeholders (or a combination of stakeholders) a differently arranged to the main educational path the learners are undertaking.

Key words: community centre, recognition of achievements, shared learning values, descriptions, and balance between individualization, socialization, and professionalization

Finding shared desired perspectives

After reporting from each table, a discussion followed in order to synthesize the six visions and provide a high level common strategic perspective as a *common visionary framework* and identify *common themes*. Different synthesis and brainstorming tools were used at this point, including, google document, flip-charts, whiteboards and post-it notes, and mind maps (mind map tools and CmapTools), which were also used in the follow-up conference calls. The co-innovation group had tried to first write the characteristics of each vision in *post-it notes* and use *a whiteboard* in order to classify and group them looking for common themes.

Figure 129 provides an example of the first classification of common themes among the six visions in Google document.

TEL-Map EU Schools cluster GoogleDoc workspace

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fx Key Features of Initial Visions

	A	B	C	D	E	F
1	**Key Features of Initial Visions**	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
2	Grouped under themes	Collaboration beyond the school's boundaries	Personalised LLL spaces	Schools as trusted open classroom connected to community	Open sharable practices & resources	Adaptive community based curricula and assessment methods (wiki example)
3						
4	TABLE 2	Collaborative peer-to-peer learning	Learner's learning activitieas are not limited by school schedule and space. S/he can continue in his/her learning activities on weekends with support of external experts.	Connected school	Teachers and students to become content producers	Tools for integrated formative assessment
5		School Management Supporting active Networking & Collaboration across stakeholders		Seamless learning	Usable, hassle free, ready to use technologies to provide for seamless learning	Assessment geared to new competencies
6						
7						Peer Assessment
8						Empower teachers to design assessment & curricula
9						
10	TABLE 3	Collaborative learning beyond the classroom with variety of stakeholders	Life profiled-based (personalized) learning used to negotiate learning	"Phase – not- age" focused schools	Distributed learning	
11			Negotiating learning between teacher and learner		User generated learning material	
12						
13	TABLE 4		Ability to configure the learning space as the needs emerge	Agreed by parents, teachers, students. Mix of pedagogical approaches	Digital and non-digital resources are used as and when appropriate (teachers and students choose)	Empower the learner allowing pupils to follow their own interests and passions
14			Learning embedded in spaces: environments represent means to solve problems & understanding (no boundaries between disciplines)	A team of teachers is responsible for a class of students	No top down directives related to what resources are used and when	Adaptable curriculum to children needs
15			Teachers, parents and students develop the learning agenda for individual pupil connected to their needs			

Figure 129. example from Google Document of classification of visions' elements in common themes

The shared vision for European schools, *"creative learning environments"*, focused on "empowering the Learner in their own ecosystem, which includes their teachers and school, their local community, and the wider society. The intent was to empower the learner to draw upon all the people, influences and resources available to them and use the knowledge gained to develop effective agency in their local community, gradually extending this out towards the wider global networks in which they are embedded. A further aim was to empower those that can help learners (both at a cost and for "free") through a policy of openness characterized by:

- Collaborative learning, seamlessly integrated with society
- Learning with and from the environment, community and business worlds.
- Strategies for negotiated Curriculum and Assessment, adapted to the Learners' needs."

Under this high level vision, "learning is enabled by open, readily adaptable practices and resources, together with open values, ways of recognising quality in learning and empowering all to participate in agenda setting, curriculum, learning strategies and assessment. Emphasis was put on the school as a trusted open learning environment connected to the local community and beyond."

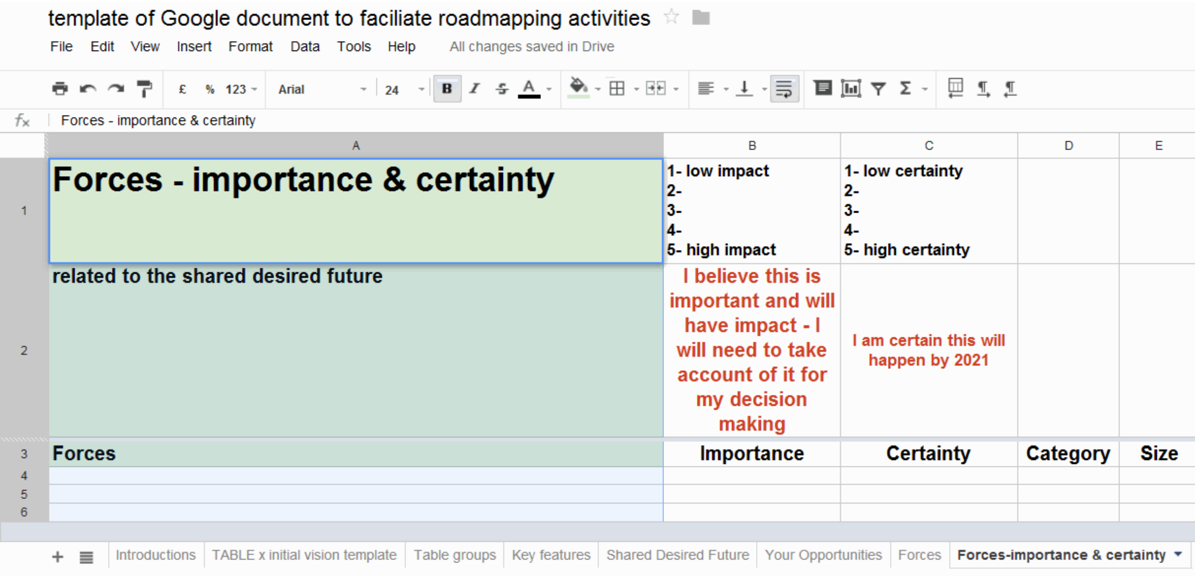
Developing Future contexts

The next step in the workshop was for the group to develop a better shared understanding of the wider contexts they are operating in, and the possible ways they thought they might develop in future. The aim of this task was a) to help the group surface and examine their collective, and often conflicting, expectations and assumptions about the future, b) provide input to the observatory for scanning and monitoring signs of change and c) provide input to the observatory for developing the context scenarios.

A typical set of steps involved would include:

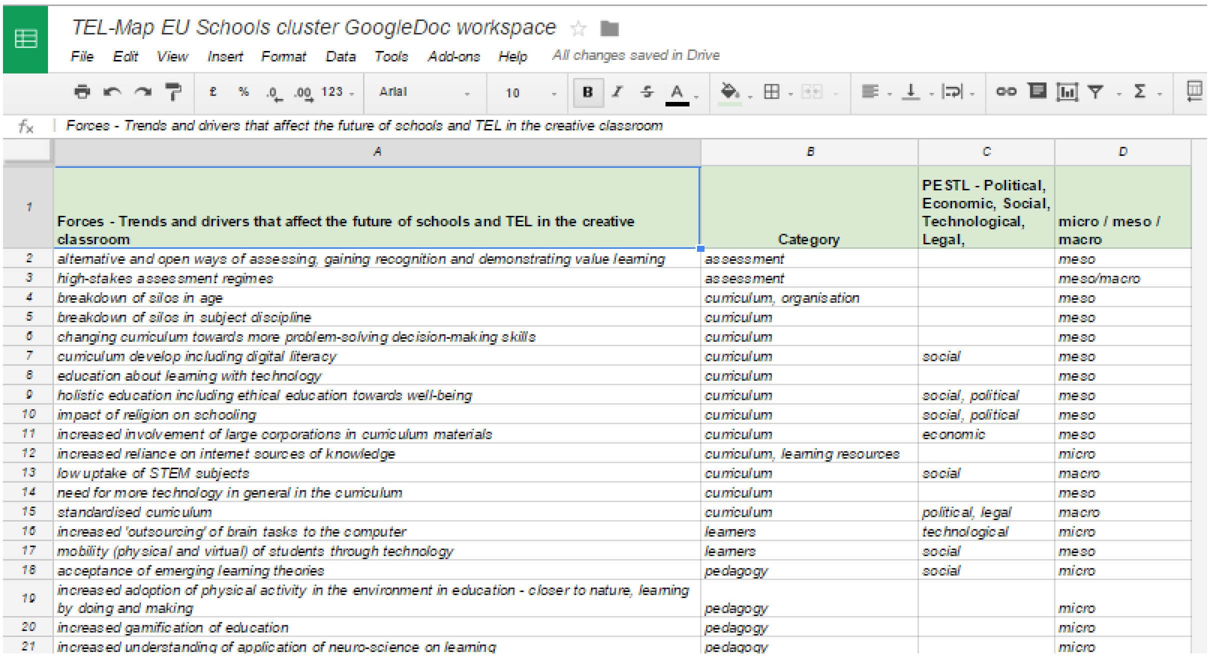
- Brainstorm a list of driving forces.
- Discuss these, in small groups if the number of participants is large, in this case about 60 people, and then, as a whole group, rate them for impact on the shared desired future and its implementation.
- Of these, the more important or higher impact ones are selected and the possible directions they might take are considered.
- The group then rates these for their confidence in the direction each driving force is likely to take in future.
- The results are divided into roughly two groups: those with reasonably high confidence and those with low confidence.
- The key uncertain drivers are then examined.
- The high confidence drivers and trends, which are those whose trajectory, the group feels they can predict with reasonably high confidence, are also grouped to form the common core that will later be used to inform all context scenarios.
- These in turn provide input and a framework to the observatory for creating the four context scenarios during the next workshop *(workshop 2)*.

Figures 130,131,132 and 133 provide some examples of this work from the co-innovations group’s Google document.



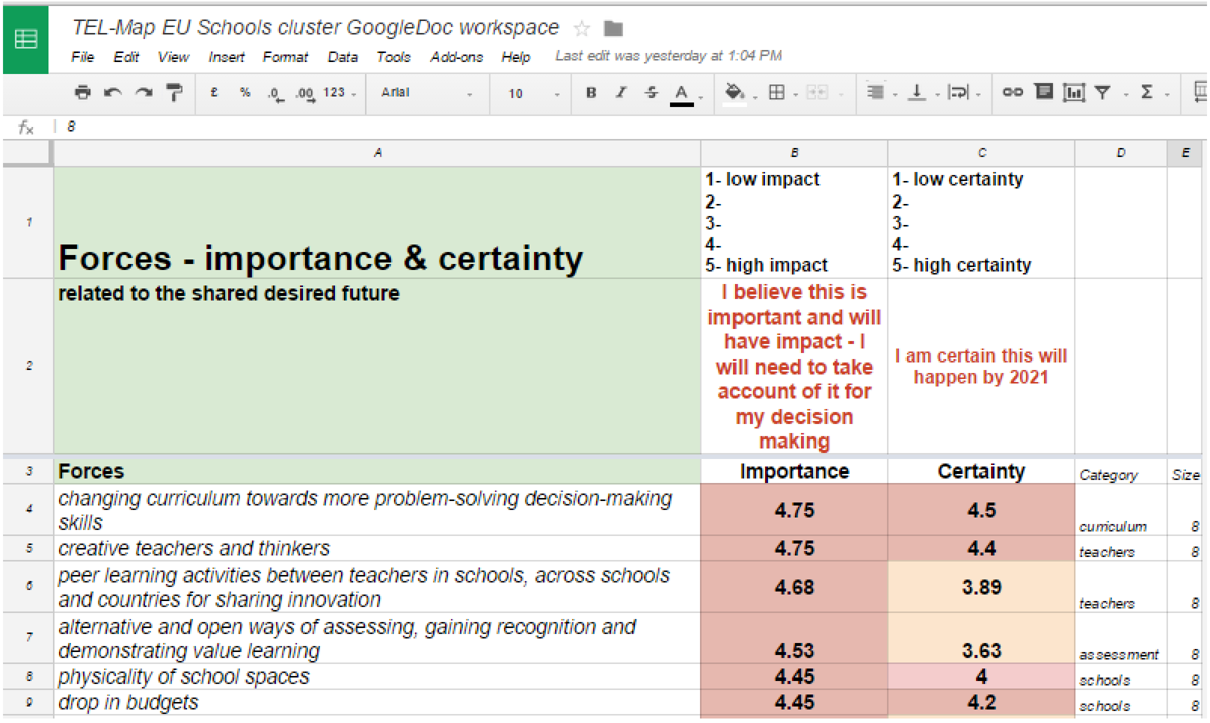
	A	B	C	D	E
1	Forces - importance & certainty	1- low impact 2- 3- 4- 5- high impact	1- low certainty 2- 3- 4- 5- high certainty		
2	related to the shared desired future	I believe this is important and will have impact - I will need to take account of it for my decision making	I am certain this will happen by 2021		
3	Forces	Importance	Certainty	Category	Size
4					
5					
6					

Figure 130. Forces – important & certainty template used in TEL-Map school co-innovation group



	A	B	C	D
1	Forces - Trends and drivers that affect the future of schools and TEL in the creative classroom	Category	PESTL - Political, Economic, Social, Technological, Legal,	micro / meso / macro
2	alternative and open ways of assessing, gaining recognition and demonstrating value learning	assessment		meso
3	high-stakes assessment regimes	assessment		meso/macro
4	breakdown of silos in age	curriculum, organisation		meso
5	breakdown of silos in subject discipline	curriculum		meso
6	changing curriculum towards more problem-solving decision-making skills	curriculum		meso
7	curriculum develop including digital literacy	curriculum	social	meso
8	education about learning with technology	curriculum		meso
9	holistic education including ethical education towards well-being	curriculum	social, political	meso
10	impact of religion on schooling	curriculum	social, political	meso
11	increased involvement of large corporations in curriculum materials	curriculum	economic	meso
12	increased reliance on internet sources of knowledge	curriculum, learning resources		micro
13	low uptake of STEM subjects	curriculum	social	macro
14	need for more technology in general in the curriculum	curriculum		meso
15	standardised curriculum	curriculum	political, legal	macro
16	increased 'outsourcing' of brain tasks to the computer	learners	technological	micro
17	mobility (physical and virtual) of students through technology	learners	social	meso
18	acceptance of emerging learning theories	pedagogy	social	micro
19	increased adoption of physical activity in the environment in education - closer to nature, learning by doing and making	pedagogy		micro
20	increased gamification of education	pedagogy		micro
21	increased understanding of application of neuro-science on learning	pedagogy		micro

Figure 131. Example of PESTLE and Macro/Micro analysis of forces in co-innovation Google document



TEL-Map EU Schools cluster GoogleDoc workspace

	A	B	C	D	E
1	**Forces - importance & certainty**	1- low impact 2- 3- 4- 5- high impact	1- low certainty 2- 3- 4- 5- high certainty		
2	related to the shared desired future	I believe this is important and will have impact - I will need to take account of it for my decision making	I am certain this will happen by 2021		
3	**Forces**	**Importance**	**Certainty**	Category	Size
4	changing curriculum towards more problem-solving decision-making skills	4.75	4.5	curriculum	8
5	creative teachers and thinkers	4.75	4.4	teachers	8
6	peer learning activities between teachers in schools, across schools and countries for sharing innovation	4.68	3.89	teachers	8
7	alternative and open ways of assessing, gaining recognition and demonstrating value learning	4.53	3.63	assessment	8
8	physicality of school spaces	4.45	4	schools	8
9	drop in budgets	4.45	4.2	schools	8

Figure 132. Forces ranking by co-innovation group at Google document.

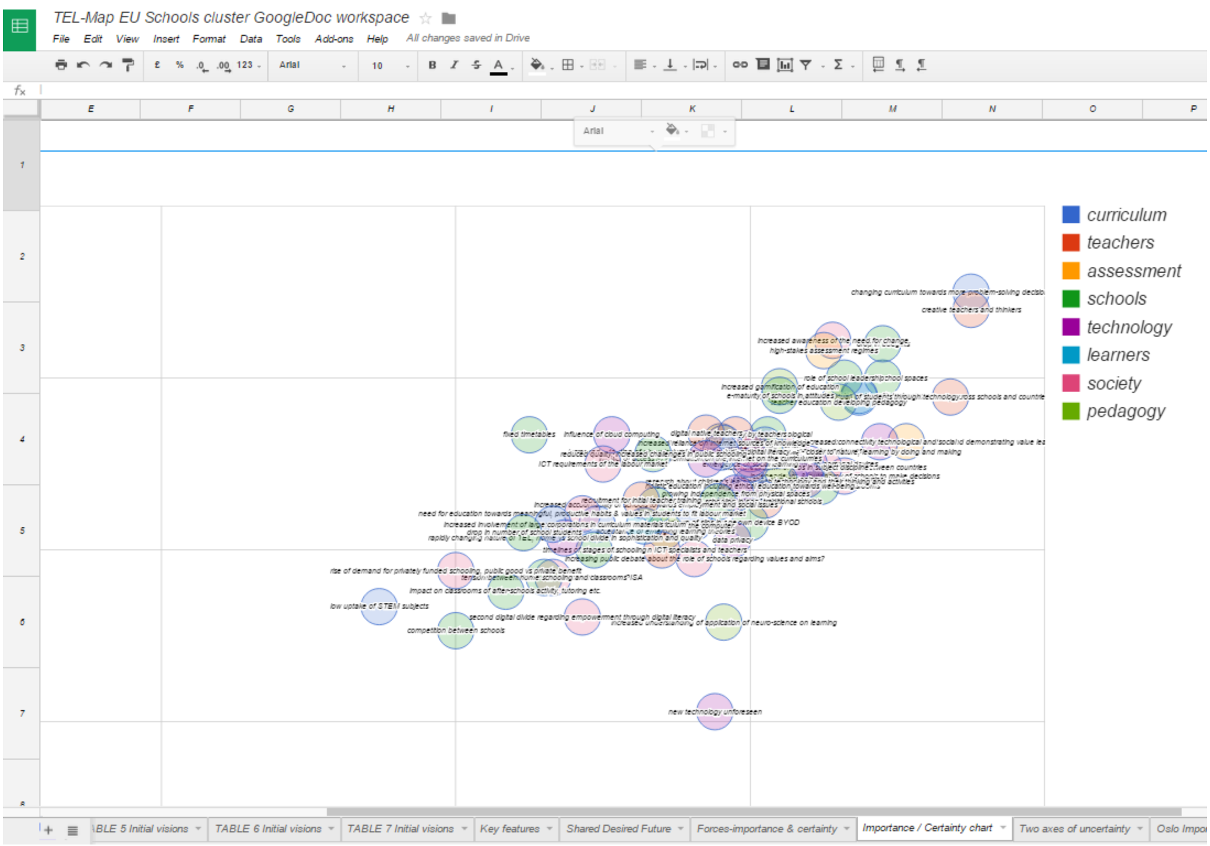


Figure 133. Importance/Certainty chart at Google document.

Virtual collaboration before the workshop

Prior to the first workshop, all the participants were asked to join a Google spreadsheet document, which was developed by the TEL-Map roadmapping facilitation team, in order to facilitate the collaborative work of this group. The participants of the co-innovation group were asked to fill out a brief questionnaire, in which they introduced themselves to the yet-to-be-formed co-innovation group by setting out (See Figure 71) and where invited to share histories (see figure 118):

- Their name, organization, role in their organization, email.
- A brief description of their and/or their organisation's TEL Future Focus & Vision
- Some of the key historical milestones they see as still having a major impact on the domain

This online shared document approach was intended to maximize the benefit from the face-to-face meeting, by allowing participants to contribute before, during and after the meeting at the time and place which fitted their schedules.

Virtual collaboration after the workshop

In order to synthesize a shared perspective from the initial visions, the roadmapping facilitation team and the co-innovation participants have used an electronic mediated approach with smaller groups' meeting via Skype, google spreadsheet document and CmapTools[40] for collaborate modelling. The co-innovation participants used the software 'CmapTools' in order to develop conceptual models, identify key features, similarities and differences and find common ground for the whole group. This approach was used to model the table visions and identify core and secondary concepts. It proved helpful to look for commonalities and differences across concept maps. Examples of a CmapTools model of *vision 2* is showing in Figure 134: This was proved to be a good choice for a distributed group of people. It helped the co-innovation group to create a common language and share concepts, which is essential for going towards common goals. The finalised maps were also modelled in the Conzilla browser by the roadmapping facilitation team.

[40] http://cmap.ihmc.us/

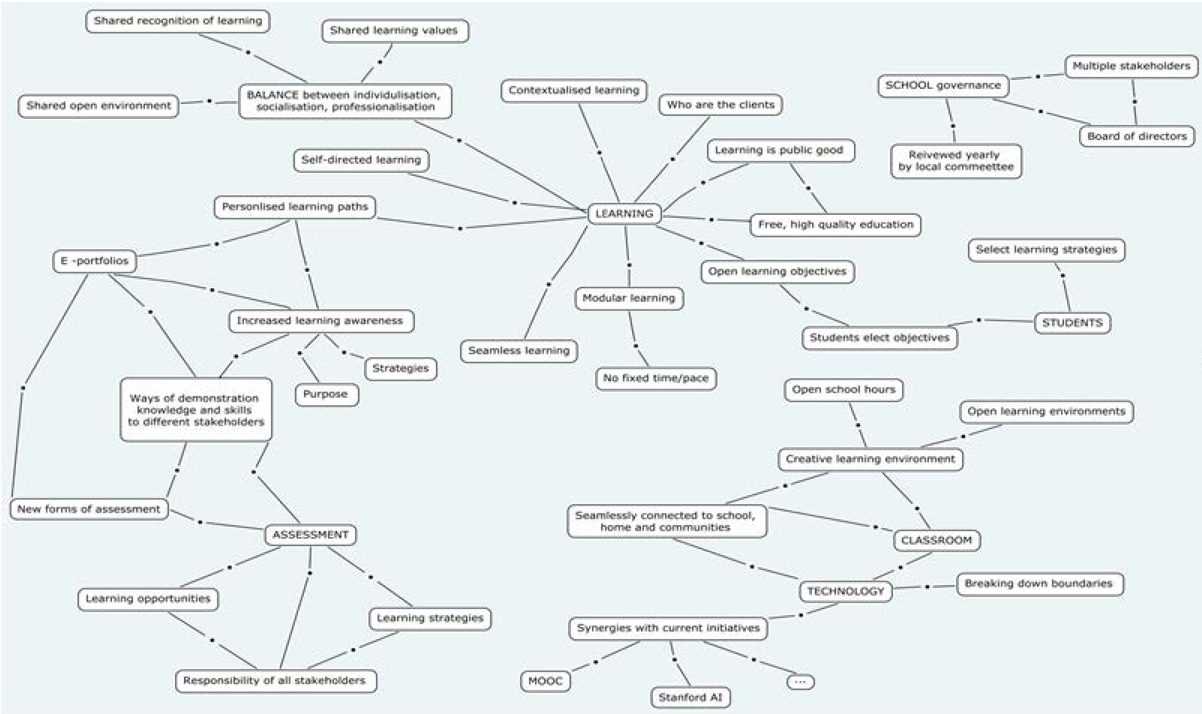


Figure 414. Vision 2: ISP SOLVER (Individualization, Socialization, Professionalization) - Shared, Open, Learning, Values, Environments and Recognition Cmap model draft

The comparison and analysis of the individual visions by the group showed that a shared vision is possible, but with variations in openness, (e.g. open and adaptable curricula versus standard but flexible in implementation) and control (e.g. school governance by a community board versus governance by teachers and education department) and with different ways of bringing about change (e.g. by EU country, region, and/or type of educational system). While the roadmapping methodology aimed to provide flexibility in the roadmaps that were generated, it was also found important by the group that the methodology itself had also to be flexible in order to accommodate the implementation of open and seamless creative learning in schools across the wide diversity of educational systems and contexts to be found in Europe. In practice, the desired futures will be realised through the contributions of different stakeholders, each operating in their own contexts. Therefore, the shared vision and roadmaps will need to be contextualised, if it is to be successfully adopted in a variety of cultural and operating environments. These environments are shaped by many factors: vendors that develop software for schools, the schools themselves in different member states, the teachers, learners and parents, local businesses, researchers, etc. Therefore, mapping these stakeholders (cartography activities) and establishing a synergy between the different types of stakeholder communities (such as research & development, sectors-stakeholders, and policy making, etc.) is essential to arrive at common directions and clear future visions which have a good chance for implementation. The roadmap design should be capable of supporting both ends of the shared vision related to openness and control and able to scaffold the process incrementally. There was also a need *to separate "concerns" and "realms of responsibility"*, making the means to work towards common goals. For example, software companies that provide learning solutions as commercial software and services will have some influence on the future of European schools. Analysis of their plans and how this may potentially shape the future is an important observatory task *(e.g. state of play and state of the art activities).* The software that is to be used in the near future will in turn be a factor shaping the requirements for developments in the longer term future. This was reflected in *workshop 3 (industry involvement),* as well as in the state of the art and gap analysis services provided by the TEL-Map observatory. After the development and presentation of the initial table visions, a modelling exercise took place in order to map the elements in the visions statements, look for commonalities and classify them. The concepts of each vision then were compared and five common themes were derived (see Figure 135). This work started during the workshop and continued via online consultations in smaller groups. These five themes updated the initial themes that had been identifying during the workshop (see Figure 129 above).

Figure 135: The five themes of the vision as synthesized from the descriptions and concept maps developed and refined by the co-innovation group (source[41])

During the online meetings, some dimensions emerged from the visions and themes as opportunities for innovation, as shown in the following diagram (see Figure 136).

[41] http://www.learningfrontiers.eu/?q=content/themes-shared-desired-future

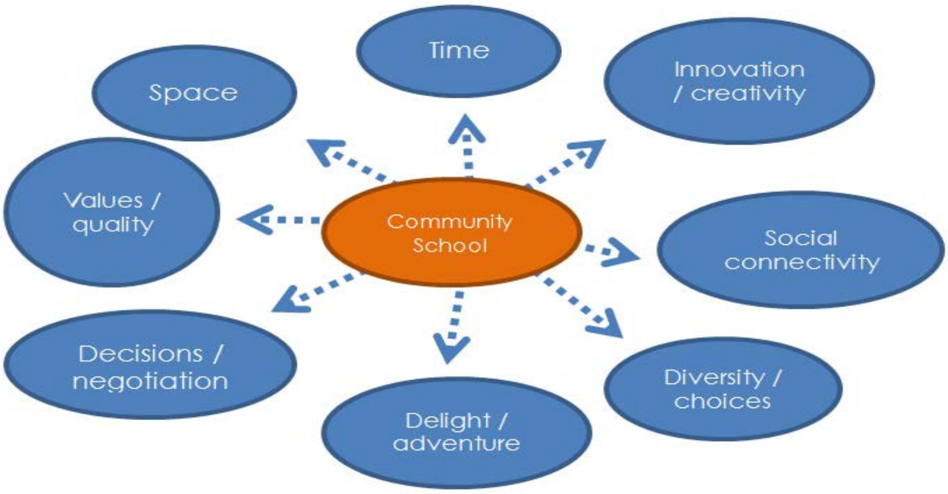


Figure 136. Dimensions of opportunities in vision statements

Grouped under each dimension are elements that were specified in the visions.

Space & Time

- Seamless learning/seamless school: connect formal, informal, non-formal learning;
- Open in all times and all places, freedom in space and time
- Technologies to augment reality (AI, Gesture based, cloud and mobile)
- Ability to participate globally and locally

Decisions/Negotiations

- Technology as an enabler of making choices and creating contexts
- Negotiated learning (based on individual profiles and learning paths)
- Active participation by learners and other stakeholders in the assessment process
- Promoting self-awareness of learning paths/ achievements
- Self-direction/ownership of learning

Innovation/Creativity

- Teacher led innovation (need to promote)
- Teacher is allowed to make errors
- Learners have permission to come up with unexpected solutions

Social connectivity

- The connected student

- Distributed and mixed age classes
- Profiles as life-long story-telling data
- Distributed and shared materials

Values/ quality

- Balance between socialization, personalization and professionalization
- Teaching profession as highly-valued within society

Decisions/Negotiations & Values/quality

- Curriculum defined by valuing knowledge rather than prescribed them: wiki of what is valued by the community - students, teachers, parents, employers, researchers, experts
- Education department: from watch dog to a mediated approach
- Open curricula

Diversity/choices

- Learning variation: diversity of approach to learning via personalized learning portfolios
- Technology as an enabler to make choices: helps student to develop options outside the school

Diversity/choices & Social Connectivity

- Variety of assessment methods
- Breaking down the boundaries and creating contexts

Diversity/choices and Decisions/Negotiations

- Multiple stakeholders governance structure

Innovation/Creativity & Values/quality

- Learning to be a change maker (the future depends on you)

Delight/Adventure

- Gamification

The co-innovation experts were asked to identify possible innovation opprortunities that they/and or their organisations see in each of the themes. Figure 137 provides an example related to theme 5 adaptive school from Cmaps models. They were also asked to inform the introductory page in the shared Google document (see exampe in Figure 138).

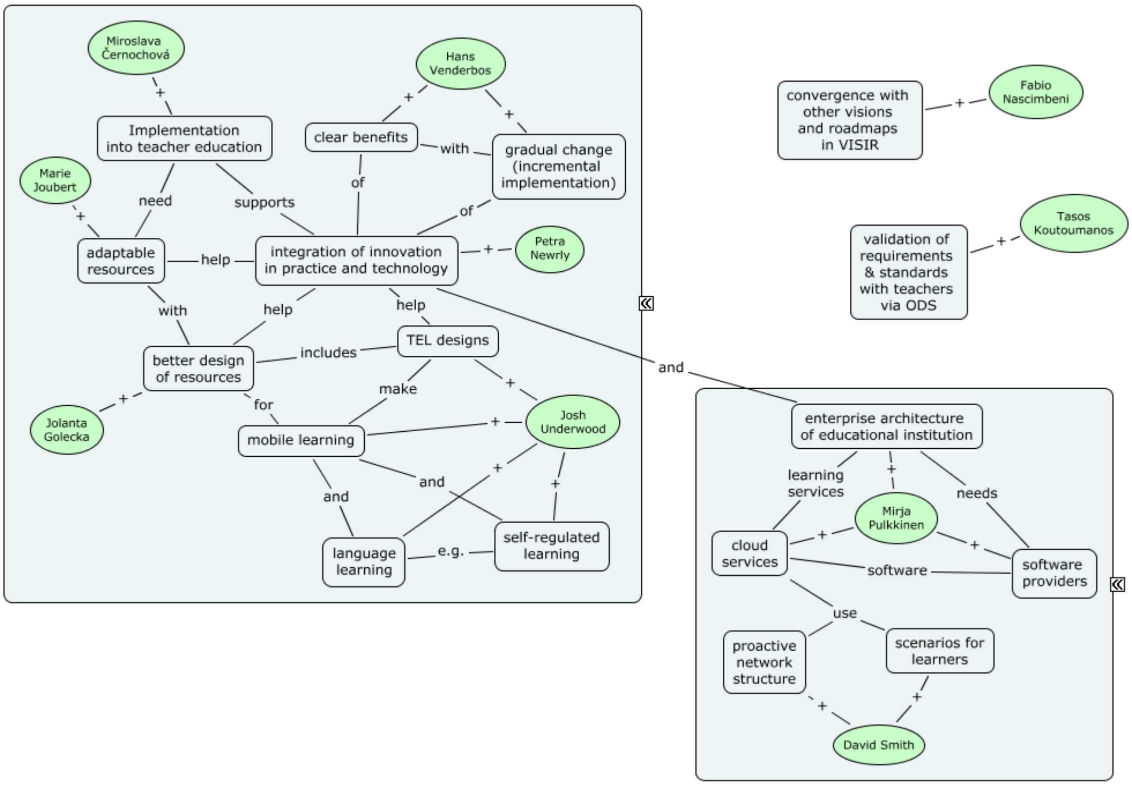


Figure 137. Opportunities for co-innovation participants in vision 5. Adaptive School.

Organisation	Role	Email (to share with this group only)	Opportunities for your organisation/project in the Shared Desired Future	Your / your organisation's TEL Future Focus & Vision	Your / your organisation's TEL future Issues
MTO	Scientific Coordinator NEXT-TELL project	peter.reimann@sydney.edu.au	The NEXT-TELL project is part of the "Classroom of the Future" track of the EC's IST program. In addition to having our own vision of the future classroom, I am very interested in other experts' and stakeholders views of what the future classroom will look like, and indeed, if there will be a classroom in the future.	In the 21st Century Classroom, ICT is used to engage students in meaningful learning activities, and to provide teachers and students with nuanced information about learning when it is needed and in a format that is supportive of pedagogical decision making, thus optimizing the level of stimulation, challenge, and feedback density. Teachers innovate continuously and collaboratively the use of ICT for teaching, learning and formative classroom assessment.	21st Century learning and assessment: How to foster and diagnose the growth of competences that develop over years, across locations, across subject matter, and across social configurations?
Beuth University of Applied Sciences Berlin	Professor for Digital Media & Diversity	buchem@beuth-hochschule.de	I am interested in sharing ideas and transfering the experience into higher education context and vocational training	Creativity and innovation, diversity-oriented education, gender diversity, social inclusion of different groups within higher education, employability	How to implement flexible models in higher education catering for diverse needs? How to make technical and engineering fields of study and professions attractive to females? How to ensure and manage cultural diversity in higher education, in digital media and enterprises?
University of Nottingham	Senior Research Fellow	johann.riedel@nottingham.ac.uk	I am representing the GALA Network of Excellence on Serious Games. We are aligning and producing joint research on Serious Gamess in education and industry for various applications.We are interested in the application and development of SGs for education. See www.galanoe.eu. Personally, I am interested and researching on IT/TEL adoption in companies, and in evaluation of serious games...	Use and development of SGs in education and other fields.	How to integrate SGs into educational contexts; how to evaluate the effectiveness of SGs; How to raise the adoption of SGs.
Liceo Scientifico Statale "Cosimo De Giorgi" Lecce (Italy)	Teacher and Coordinator of English Department, Coordinator of "ELvis" (LLP project)	sweetblood56@gmail.com	"ELvis" is a project based on the use of ICT to connect students and teachers across borders. We are researching new approaches to teaching, learning and assessment, therefore we are very interested in sharing experiences and exploring new approaches.	We believe in research based learning for teachers and students. We encourage students to create, not simply consume knowledge. Teachers and learners explore their new roles together. All participants are researchers, building knowledge and recording their progress for the benefit of others.	How can we encourage creativity and independent learning? How can we make a real connection between the classroom and the (local and global) community?

Figure 138. Example of Opportunities for co-innovation participants in schools' visions.

Observatory work:

The facilitation team provided access to the co-innovation inputs to the observatory network. The observatory included this input in their scanning and monitoring analysis.

6.5.2 Workshop 2: Context scenarios

Participants: observatory's experts and roadmapping facilitation team

Aims of the workshop

Workshop 2 aimed to use foresight methods such as scenario planning in order to surface assumptions and key areas of uncertainty, to explore the wider context and to project plausible alternative futures that between them capture the range of uncertainty. At a later stage, when the initial roadmaps had been developed by the co-innovation group, they were set out against each of the context scenarios in order to stress-test the roadmaps and update them with possible alternative roots. The actual context scenarios in this case study were developed by the intelligence network or technology and policy foresight experts and then discussed with the co-innovation groups. In 'Dynamic Roadmapping' methodology, this also depends on the resources and the way the process is set up, for example people from the co-innovation group can also take part in the process or they themselves can develop the context scenarios with input from the observatory. The scenario activities were supported by the strategic analysis of weak and strong signals of future TEL trends via the roadmapping alert system (Observatory).

Workshop steps and templates

Reducing the number of uncertain drivers to two axes of uncertainty is often the most difficult step in this workshop and although there are several methodologies for doing this, it is more of an art than science. Through further discussion, the uncertain drivers were then considered in depth for mutual dependencies e.g., if one changes, which others are likely to change also - and those with mutual dependencies are clustered together. The result is several clusters, which should be mutually independent. The two largest clusters were then used to create two major "axes of uncertainty" which were set at right angles to each other to create a 2x2 matrix. Each resulting quadrant then created the framework for one possible future scenario. How much to write for each one is always an open question. There needs to be enough for people to understand what the world would be like and for some this can result in quite detailed, multi-page descriptions. However, given the 'Dynamic Roadmapping' agile approach, where everything remains up for revision in the light of future changes, the team was advised to keep them small to start with, perhaps only a few paragraphs, and elaborating them later as needed.

Two alternative ways to work are presented below, which are slightly different in the way the 2 axes of the scenario matrix are derived:

A.

1. Choose the most important AND the most uncertain trends and attempt to group these and find two dimensions of uncertainty (use post-its)
2. These are set as the two dimensions, which identify four quadrants of possible future context scenarios
3. Describe these quadrants to enhance understanding of the kind of future they represent (and other resources they require)
4. Finally name the axes and form the 2x2 matrix scenario
5. Give a name to each one of the 4 resulting scenarios
6. From these context scenarios set out key signals to watch for indicating the direction of their development

Or

B.

1. The high impact, low confidence set of trends and drivers are identified. (use post-its)
2. Cluster forces: move the post-its around, so that forces related to each-other are grouped together.
3. Group all forces to 2-3 axes of uncertainties (try not to force-fit forces into clusters which they don't belong).
4. Develop the end point of the axes (extreme states or polarities - the clustered forces will play out) - if time, try to develop the two extreme outcomes of each force in the axis cluster before you combine together to two outcomes.
5. Finally name the axes and decide on the final 2 independent ones.
6. Give a name to each one of the 4 resulting scenarios.
7. From these context scenarios set out key signals to watch for indicating the direction of their development.
8. Locate the strong trends in all scenarios since the probability of occurrence is very high so they are expected to play out in all scenarios.

The group followed the second approach to develop its scenarios. The input from the workshop one (forces and their ranking of importance and certainty) was the starting point of this work. Additional forces were brainstormed using also the PESTLE analysis input from the observatory. An analysis of all of the forces led to a grouping in terms of some key directions.

These were identified as:

- Decline in public funding
- Digital literacy
- Openness in curriculum
- Procurement of TEL
- School identity
- School leadership
- Teacher identity
- Drivers and Potential blockers

See example in Figure 139 below:

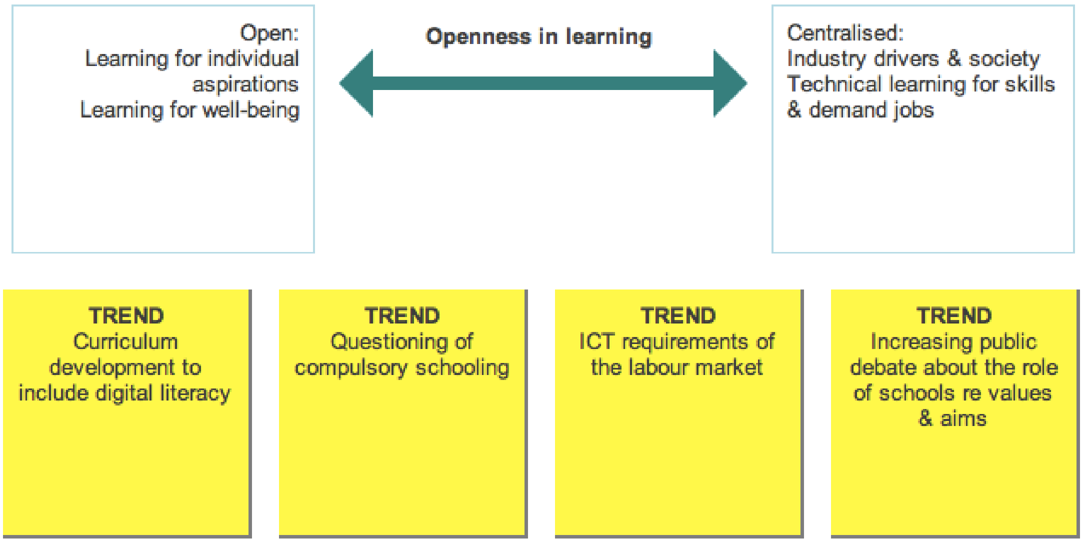


Figure 139. Openness in curriculum

A list of drivers that could influence the wider school contexts were also identified as well as some potential blockers to change (see Figure 140).

The final step in developing the context scenarios is to outline a 'history' for each: what significant events or changes can be expected to take place if the world is to evolve from where it is now to the world envisaged in the given scenario. Outputs of these workshops were tensions; drivers and 2 axes of uncertainty which were used to formulate the following 2 by 2 scenario matrix (see Figure 141).

Figure 140. List of drivers and potential blockers

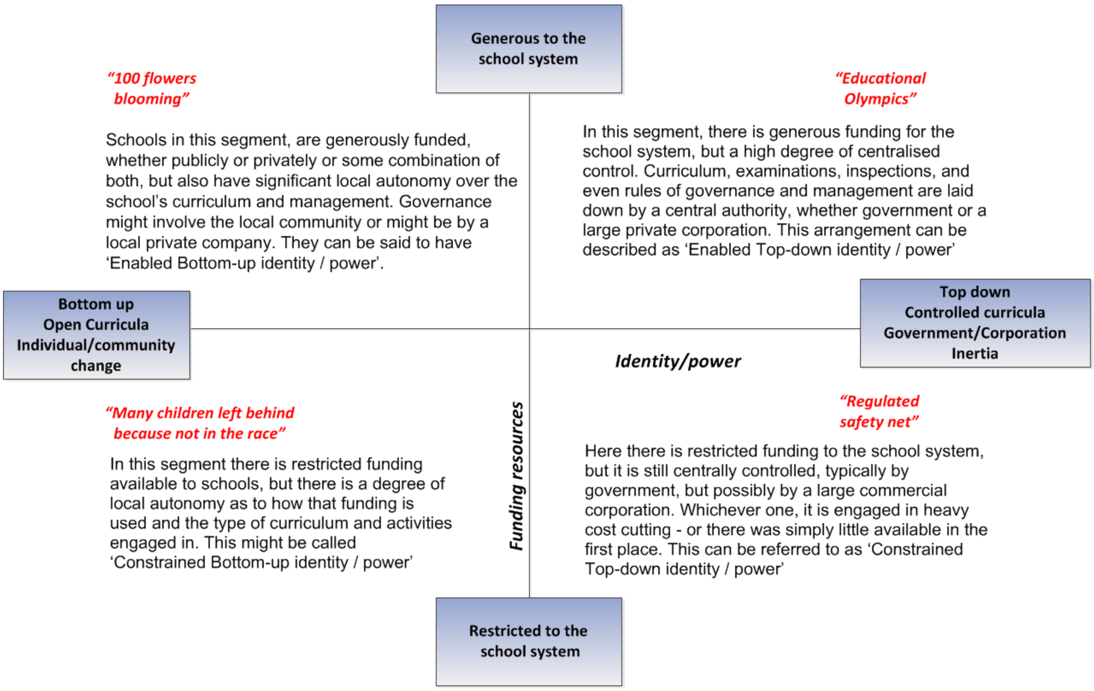


Figure 141. 2 by 2 Context scenarios matrix (Naeve & Kamtsiou 2013)

While more than two axes were certainly possible, each additional axis doubles the number of scenarios that would need to be considered, and planning for all these possible futures is usually too great a burden, so the four that were deemed the most critical were taken to be sufficient. However, with the increasing global turbulence resulting in perhaps multiple significant drivers changing simultaneously, it may be that missing out on one or more of these could jeopardise the success of the roadmapping effort. The team must decide, based on the number of critical driving forces, the time available and criticality of the task in hand, how many possible futures to consider. Current capabilities of data analytic techniques could provide simulation analysis for a large number of scenarios, when digital data is available.

In addition, the scenarios typically generated in this kind of scenario planning exercise are pitched at some chosen point in the future. While this is the case here, the team realised that they were dealing with an unusually complex situation: schools in Europe operate under very different government, cultural, social and economic circumstances. There are privately and publicly funded schools, governance can be national, regional and/or local, and different governments have different educational priorities and policies. This presents particular problems when seeking to roll out innovations, even when, as in the co-innovation visions, they were widely recognised as much needed. The task of establishing Creative Learning Environments across European schools will therefore vary according to the these different specific contexts and the roadmaps for doing so are likely to differ to varying degrees according to the specifics of each education system's particular circumstances. Therefore, while the context scenarios developed can be used in the usual way to characterise uncertainties about the future, they can also be used to characterise current educational contexts and thus, the starting points for specific implementation programmes for the Creative Learning Environments. Therefore, as also concluded in workshop one, while certain core elements of Creative Learning Environment visions were similar, some aspects may needed to be changed and some additional elements or tasks may needed to be added. These four quadrants were used by the co-innovation group in workshop 5, stress-testing initial roadmaps, in order to characterise different educational domains or jurisdictions, both in the present and the future. The co-innovation participants were asked to consider their current context in these terms as a way of addressing the diversity of educational provision. They may be operating in one or several of these types of context and their roadmap may need to be adapted for each, taken as a starting point. They then considered how their current context may evolve in future, possibly moving from one quadrant to, or towards, another, and whether your roadmap or indeed your desired future might have to be adapted accordingly. The quadrant descriptions were kept relatively lightweight and the co-innovation participants had the possibility if they wished to characterise them further, but within the given degree of funding available and location of control of each quadrant.

Prior to the workshop

The work on uncertainties done previously by the co-innovation group was provided to the workshop participants. The workshop participants also used the results from the observatory intelligence, on PESTLE drivers, trends and weak signals (see examples in previous section: 6.3.2, 6.3.3, 7.3.1).

After the workshop

The results were provided to the co-innovation group, which used them in order to further discuss and update the context scenarios. The updated matrix was modelled and presented in Conzilla and in learning Frontiers portal. The results were also provided to the industry participants prior to the Industry workshop (*see workshop 3 below*).

6.5.3 Workshop 3: Industry perspectives

Participants: facilitation team and 22 industry participants (e.g. solutions developers, software developers, tools developers, publishers, etc.)

Aims of the workshop

The workshop was co-located with the EC-TEL conference on *19th September 2012 in Saarbrücken*. This event was chosen because this particular EC-TEL conference was led by the industry and had a specific industry track. The goal was to capture the ‘voice of the industry’ on shaping TEL futures. The aim of the workshop was to explore and communicate the relationships between stakeholders' needs (expressed in the co-innovation group's visions) and industry solutions & technologies. The workshop answered the questions: What can industry players provide to the co-innovation group and at what stage or under what circumstances would they be willing to join? The goal was to map *innovation opportunities,* as they were perceived by the industry, to the co-innovation visions and themes and identify potential technological solutions. The innovation opportunities, identified by the industry, were explanations of the visions in terms of the industry's contribution to concrete future achievements. In 'Dynamic Roadmapping' it is assumed that that change will happen through seizing opportunities, which may or may not be apparent in the initial vision and strategic directions of any group.

Steps and templates

The industry participants were asked to; a) identify *opportunities* in the visions developed by the co-innovation group; b) describe *value propositions* which would address these opportunities; c) identify the *main features* of the solutions offered and c) the *market drivers* from the perspective of the stakeholders (customers). For example, why are these proposed innovations important to the stakeholders? It was stressed that the elaboration of the desired future should include the potential benefits to potential customers. In addition, participants were asked to d) *identify gaps* between the desired futures described in the visions and today's state of the art in the area and current practices, and e) to identify *other types of gaps* besides technology gaps. These are any kind of missing skills, competencies, practices, or issues that need to be addressed in terms of political, legal, economical, and social factors in order to overcome the obstacles. They also included f) *any adoption gaps* that should have been addressed in order for the value propositions to reach their final users. The outputs of the workshop helped the co-innovation group to understand and evaluate the performance capabilities of current industry offerings, and the gaps between the current offerings and the ones required by the vision.

The focus of the workshop was therefore to discuss the co-innovation's visions, generate further ideas that are relevant to the market and to externalise and describe these ideas in a way that are understood by all stakeholders. The results from this analysis can be found at[42] and (Naeve & Kamtsiou 2013):

A Google Document was created by the roadmapping facilitation team to be used prior, during and after the workshop with the industry.

The template for recording steps and outcomes of the workshop are illustrated in the Figure 142 below:

[42] http://www.learningfrontiers.eu/?q=content/industry-input

1. What are the innovation opportunities for this vision?	*(Where is the strategic focus? Major possibilities for innovation? which part of the vision –scope, position. Start with "There is a European/global opportunity for…..")*
2. The value proposition of the offering/idea that will make a change	*This will be delivered by....(The value propositions of the offerings/ideas that will make a change) (What?) (what is the offering and its value drivers: defines usage)*
3 What current and future technologies can best support your value proposition (vision) and how?	*What current and future technologies can best support your value proposition (vision) and how? (How?) what technologies are more important? What are the critical requirements?)*
4 What will be the impact on the vision? Which part?	*How the value proposition will help the realisation of this vision in terms of concrete achievements*
5 What is the current maturity of the proposed technologies?	*Technology assessment. Don't restrict your selves to propose more basic or challenging technologies but they should be focused on clear goals of the future vision*
6 What are the Market / Technology gaps?	*Current Market situation, what are the gaps from the current market solutions offered today.*
7 What further Research & Development would be needed?	*R&D related areas*
8. Key Actions	*Recommendations for actions in order to close the gaps*
9. Other Enablers or Barriers (please specify E or B)	*Besides technologies*
11. Assumptions/preconditions	*What are the assumptions and preconditions made in your analysis above*

Figure 4242: Industry engagement workshop template ((Saarbrücken 2012)

Observatory work prior the industry workshop

TEL-Map observatory team had started a consultation with TEL providers based on an online survey and local interviews at several TEL trade fairs/exhibitions. These findings were enriched by an extensive range of resources, current research (EC projects and TEL conferences and blogs) and market intelligence in order to identify promising learning technologies. TEL Experts from the industry evaluated the importance of future societal and educational demands and challenges, the impact of technological developments, and the importance of future research themes. In addition, they evaluated the co-innovation group's vision statements for their desirability and likelihood of becoming reality by 2020 (then reduced to five years period of time). They also assessed the co-innovation group's identification of the drivers they expected would contribute to the change of TEL and the realisation of their visions. This consultation enabled constructed a state of play in TEL industry and identified and invited TEL vendors to the workshop. The results from the surveys and interviews were also available to the workshop participants prior to the workshop at the shared Google Document.

Virtual collaboration before the workshop among the workshop participants

The workshop participants were sent in advance a Google document, for virtual collaboration;

- This document included the following tabs:
- Introductions and registration details
- Vision descriptions (developed by the co-innovation group)
- Vision models (CmapTools conceptual models)
- Drivers: Trends, factors, Tensions analysis done by the Observatory (including analysis of state of the art, and state of play in TEL)
- Innovation opportunities identified by the co-innovation group
- Template to be used during the workshop

After the workshop, the participants were asked to join Skype meetings with the roadmapping facilitation team in order to update and improve the template descriptions and also to become members of the co-innovation group. Those who agreed to join the co-innovation group were asked to provide introductions about themselves and their organizations using the co-innovation group Google document. After the workshop the results from both the observatory activities and the industry workshop were provided to the co-innovation group and were discussed in skype meetings. The co-innovation group updated its themes and CmapTools maps according to these discussions. A report was prepared by the roadmapping facilitation team which included the updated visions, themes, context scenarios and outputs from the industry workshop (EU) (schools clusters shared vision report) and was made available to the co-innovation group web space. The results from the workshops and online consultations were also mapped and linked at the Conzilla browser.

Although, the industry stakeholders should ideally be participants of the co-innovation group, in practice, it is difficult to engage a larger number of them during times of financial uncertainty. This workshop operates as a bridge between the industry players and the co-innovation group. At the end of the workshop everyone is invited to join the co-innovation group. The diagram in Figure 143 below shows the Industry engagement within the roadmapping process.

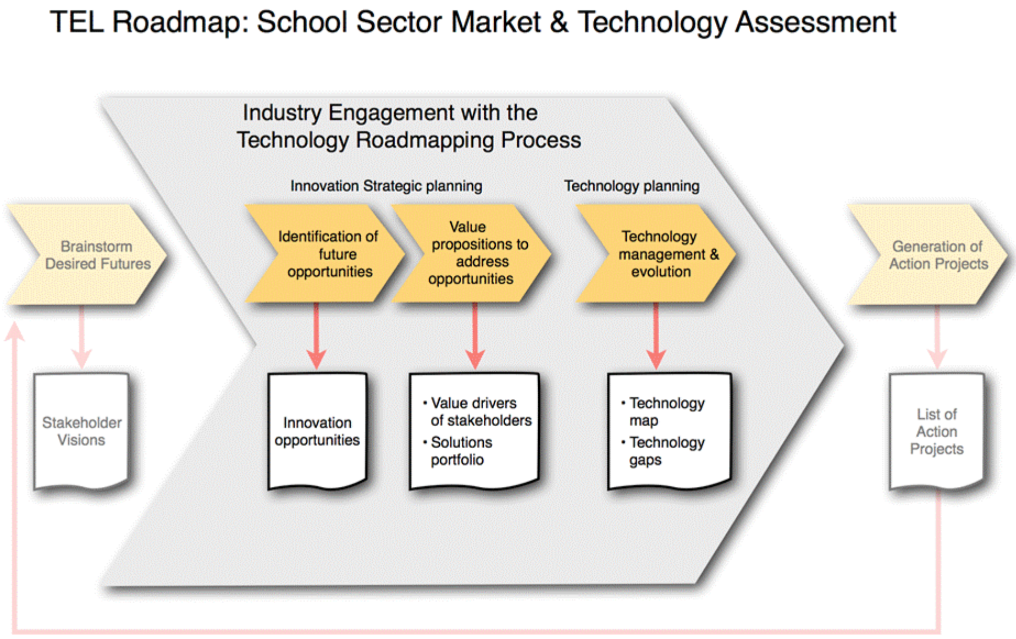


Figure 143. Industry engagement workshop processes

6.5.4 Workshop 4: Initial roadmaps

Participants: facilitation team and co-innovation group.

The aim of the workshop

The co-innovation group met again in 27th November 2012, in Berlin. The event was co-located with two other events, the Online Educa 2012, an industry focused event and the VISIR Policy foresight event. This was decided in order to facilitate the plans of several co-innovation members, who were going to participate in one or both of these events, thus integrated insights from policy and industry.

The aim of this workshop was for the co-innovation group to develop their initial roadmaps for each of the five identified themes (see Figure 135).

More specifically, the group engaged in roadmapping work in order to:

- identify the *Why (purpose)*: Derive specific drivers and goals stemming from the 5 themes of desired futures;
- Identify the *What? (roadmap design and production)*: Determine the critical elements needed to achieve these goals, and produce a Portfolio of innovations plans/designs/solutions and their development timelines;
- Identify the *How? (resources)*: Specify and select technology alternatives, technology projects and other resources that would be needed, and their timelines;

- identify *limits* that can be addressed by *Research (name projects if possible)*;
- identify *limits* that can be addressed by *policy (name policy makers if possible)*;
- connect *why, what, how*;
- Map all these to *timelines (when)* to generate the initial roadmaps for each theme.

Workshop steps and templates (learning café format)

- The group formed working groups around the themes of the shared futures.
- The groups worked around tables
- 2 group working sessions
- 1 synthesis session

All groups used large boards similar to the ones shown in the picture below in order to create their designs. Each group used a different colour post-it for their design (see Figure 144).

Figure 144. Workshop boards for creating the roadmaps. Picture from the workshop (Berlin 2012)

Steps and templates

Session 1 – Design challenge: what could it be? How it could work?

The co-innovation group brainstormed to identify opportunities for them/their organisation, then for the whole group. The co-innovation group reflected on the themes of the desired futures and formulated concrete goals in order to implement these desired futures. This allowed the group to go from the more abstract and ideal aspects usually found in the desired futures to specific targets and goals that would drive their implementation. Then, the group was asked to design solutions that would realize these goals. The participants were grouped in 6 tables corresponding to the six themes. Each table used its own colour post-it notes.

All steps on session 1:

Session 1 step 1:

- Start with identifying the specific goals related to the theme from the desired future.

- Use post-its to write the goals
- Use one goal per post-it

- Group goals if possible and use larger post-its to add group titles when appropriate

- Select goals to work on: Vote on goals and select a reduced number of goals based the grouping before.

Session 1, step 2:

- Brainstorm to identify TEL opportunities/solutions for achieving the goals (make specific concrete offers or value propositions)

    - Use mid-size post-its to write the solutions
    - Use one post-it per solution

- Outline the design:

    - Group post-its and use larger post-its to add titles if needed
    - Select final opportunities/solutions to work on. Re-write post-its if needed (vote if necessary)

Session 1, step 3:

- Map Opportunities to the goals.

- Connect the solutions to goals by drawing lines.

- Reports from each group by the group's facilitators

Figure 145 shows the session 1 output format.

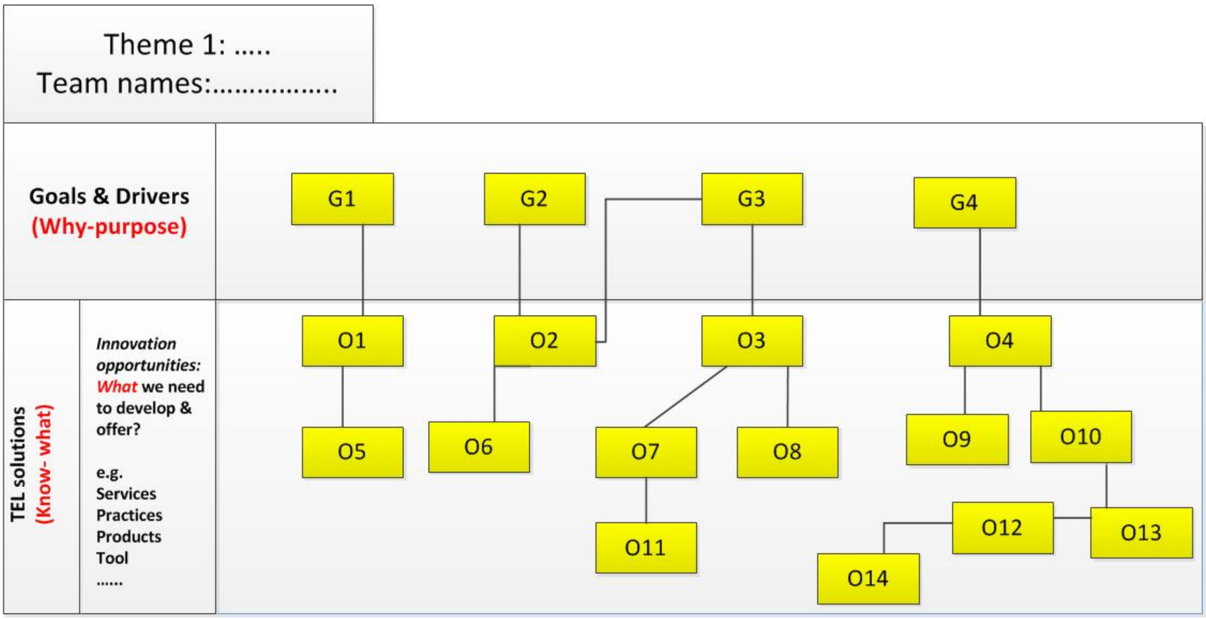


Figure 145. Session 1 output format Design challenge: what could it be? How it could work?

Figure 146 shows the respective board for the assessment theme. The post-it notes, coloured to match each vision theme group's colour id, were placed into these layers and then moved to one of three horizontal positions in order to identify their estimated time of availability – short, medium and long-term. For this theme for example the colour post-it was yellow. The other colour post-its in the board are comments from the other themes made during session 3.

Figure 146: Design challenge: what could it be? How it could work (Berlin 2012)

Session 2 -Drafting theme roadmaps & map to timelines

In the second session the focus was on technologies and other resources to develop the solutions identified in session one. Each group developed a roadmap for their theme: What needs to happen to realize the design? In what order? Who? Why? How? When?

All steps on session 2:

Session 2, step 1:

- Cross-groups consider the design of the others

- Move around other tables and exchange ideas of your designs. (Record similarities from other groups by adding some points using different colour respective table post-its.)

Session 2, step 2:

- Brainstorm to identify technology alternatives to build the TEL opportunities/solutions selected from session 1

    - Use mid-size post-its to write the technologies
    - Use one post-it per technology
    - Group post-its according to categories (example: practices, services, tools)
    - Re-name post-its if necessary, eliminate duplicates, etc. If you don't know a specific existing technology then just give a description of what it does

- Map the technology areas to TEL solutions by drawing connecting lines, rearrange if necessary

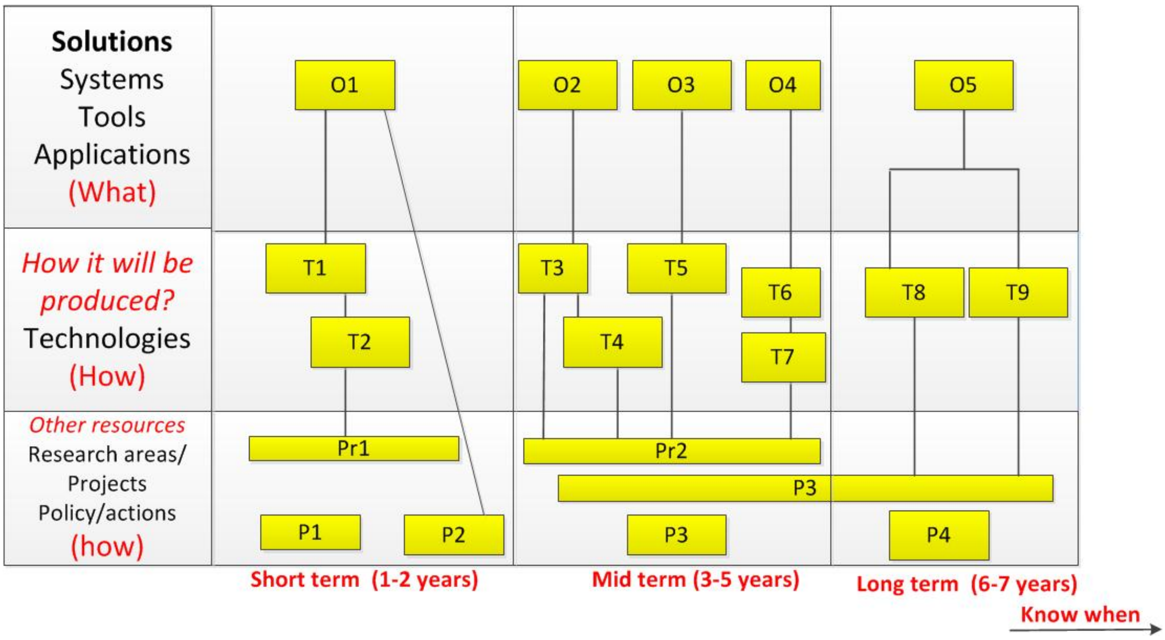
Session 2, step 3:

- Identify resources if any that need to be addressed by research or policy (use large-size stickers to write gaps)

- E.g. future research areas/projects, policy actions, practices, etc. (use mid-size stickers)

- Map to timelines: move things around to make sure they are in the right order. Re-arrange solutions and technologies in short term (1-2 years from now), mid-term (3-4 years) and long term (5-7) years

- Re-connect to goals



Figure

Figure 147. Depicts the format of session 2 outputs.

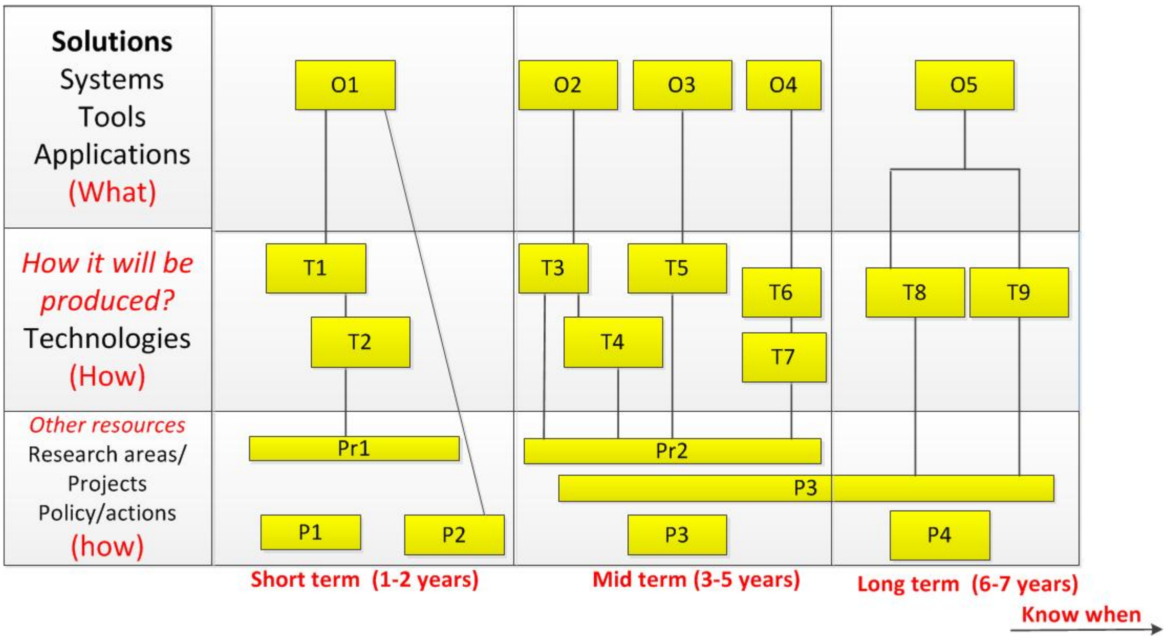


Figure 148. Session 2 output format: Drafting theme roadmaps & map to timelines

Figure 149 shows the respective board for the assessment theme session 2.

Figure 149. Drafting theme roadmaps & map to timelines (Berlin 2012)

Session 3 – How do the individual roadmaps fit together?

What are the cross-links between the roadmaps, the combined tasks, the emerging Meta themes? They then identified gaps and suggested further R&D that would be needed.

All steps on session 3:

- How do the individual roadmaps fit together?
- What are the cross links between the roadmaps? Combined tasks? Emerging meta themes? Identifying gaps: further R&D needed
- Use CmapTools for the synthesis
- Next steps: What are we going to do?
- Plans for online collaboration

During this session, each table participant was asked to visit all the theme roadmaps created by the other tables and use their theme coloured post it notes to add post-it notes as connectors to the issues that were related or conflicting with their table theme analysis.

Further post-it notes were located on the roadmap by other groups as ‘connections’, indicating the common ground with their vision themes (see Figure 150 below).

Figure 150. Post-it notes connectors, Connect Table 4 session 3: like our solution 2 (Berlin 2012)

At the beginning of the workshop a clear protocol for using the post-its were also provided to the participants, see Figure 151 below:

- Write the number of your table & session

- Write the **type** of concept: e.g "goal", "solution", "technology" "practice", etc
- Write only **one** concept per post-it
- **Summarise** the issue using one or two lines only
- Write **clearly**

Figure 431. Post-it protocol (Berlin 2012)

After the workshop

The outcomes were a large board for each theme, with post-it notes containing the roadmap elements arranged and connected. The following days the roadmapping facilitation team coded these into the Google spreadsheet of the co-innovation group. Each post-it and each linking line was recorded into a spreadsheet used as a database, a row for each kind of post-it (goal, design solutions, technologies & other resources) and linking line, see figure 152. This document was used to generate a CXL file to import into the CmapTools application. Final repositioning of the concepts and their relationships were made by hand in three days a face to face meeting of the facilitation team.

Figure 152 is an example of the Google spreadsheet.

TEL-Map EU Schools cluster GoogleDoc workspace

	ID	Theme	Theme name	Session	Type	From	To			Content	Time	Group (from brainstorm)	Other group
2	1009	1	Assessment	2	connect	4	1002			How to assess collaborative learning?		Design	
3	1015	1	Assessment	2	connect	3	1014			Pedagogies: negotiated learning		Design	Ownership
4	1035	1	Assessment	2	connect	4	1034			Social collaborative networks enable / support peer feedback and assessment		Society Perspective	Implementation
5	1040	1	Assessment	2	connect	4	1039			How to assess the application of creative skills		Society Perspective	Implementation
6	1043	1	Assessment	2	connect	5	1042			Purposeful education, qualifications defined also by stakeholders			
7	1046	1	Assessment	2	connect	5	1045			Critical action research as an alternative form of quality evaluation			
8	1048	1	Assessment	2	connect	5	1047			Embed school in the community			
9	1050	1	Assessment	2	connect	2	1049			G5			
10	1053	1	Assessment	2	connect	5	1052			eportfolio is a reflective tool for critical action research			
11	1054	1	Assessment	2	connect	2	1052			Solution 2 Portfolio			
12	1055	1	Assessment	3	connect	2	1052			Think of our solution 2 too!			
13	1057	1	Assessment	3	connect	4	1056			Links to our solution / technology on assessing collaborative / creative activities and outcomes			
14	1058	1	Assessment	3	connect	5	1056			Like our S6			
15	1060	1	Assessment	2	connect	2	1059			G1 (Active student participation with growing responsibility for learning)			
16	1061	1	Assessment	3	connect	5	1059			Like our S4			
17	1065	1	Assessment	2	connect	2	1064			G1 (Active student participation with growing responsibility for learning)			
18	1067	1	Assessment	2	connect	3	1066			New pedagogies teacher training			
19	1072	1	Assessment	3	connect	4	1071	1076		We need V.E. & games with room for creativity			
20	1075	1	Assessment	3	connect	4	1074			We have L.A. as well common need			
21	1084	1	Assessment	2	connect	3	1083			This connects to T3 "influence policy makers"			
22	1087	1	Assessment	3	connect	5				Included in our S6			
23	1096	2	Stakeholder Engagement	3	connect	4	1095			Links to social network solution		Student	
24	1097	2	Stakeholder Engagement	2	connect	5	1095			Students active and reflective		Student	
25	1098	2	Stakeholder Engagement	2	connect	1	1095			Self awareness in assessment / learners' ownership of assessment		Student	
26	1099	2	Stakeholder Engagement	2	connect	5	1095			School vision and mission		Student	

Figure 152. Google document spreadsheet example of the roadmap entries

The roadmaps were added at the Learning frontiers portal and were also modelled at Conzilla tool. Figure 153 provide an example of the Cmap model for the roadmap of the adaptive school theme.

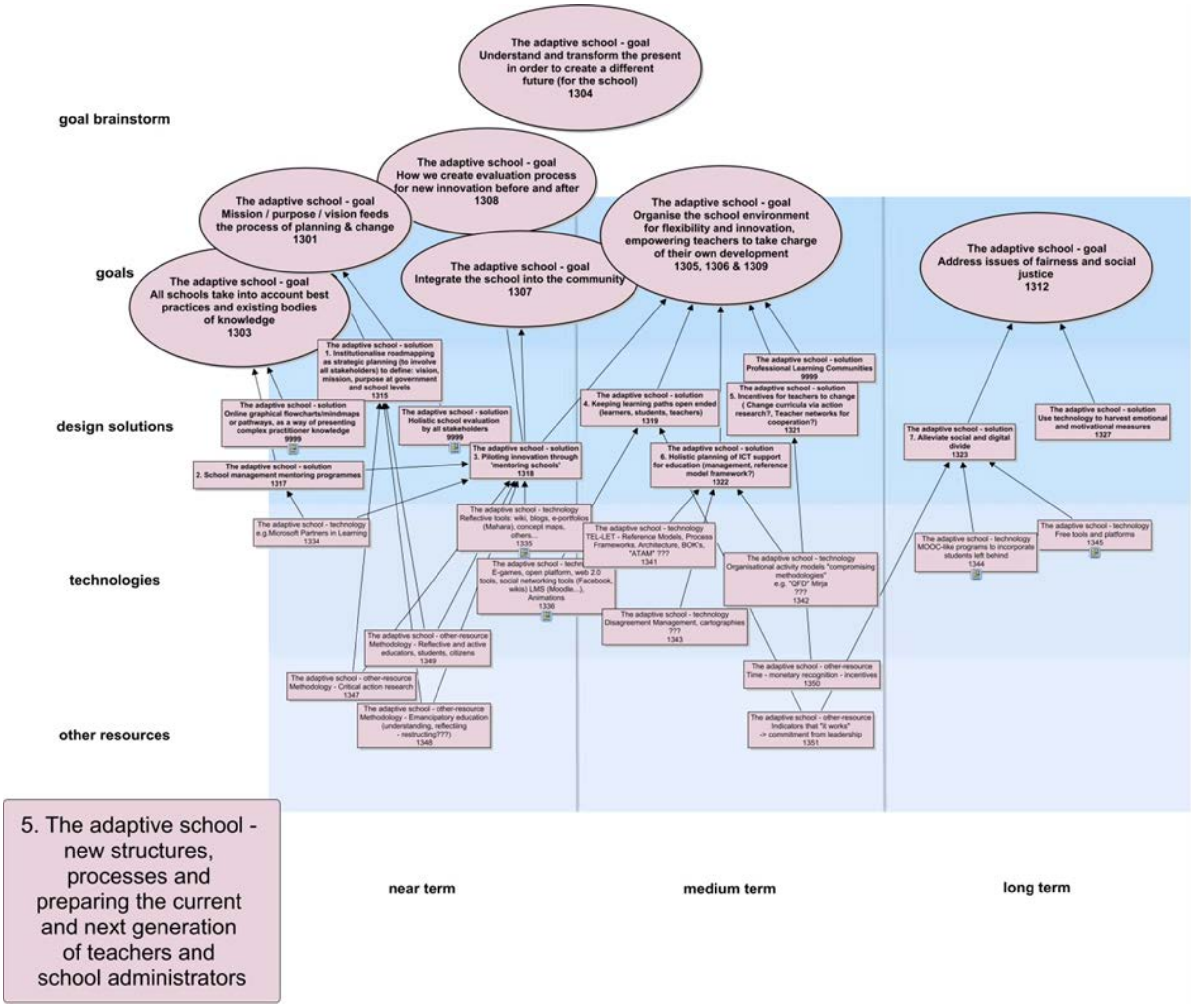


Figure 153. CMAP model Roadmap for Adaptive school theme, http://cmapspublic3.ihmc.us/rid=1LDWZJYM2-61Q560-101P/Roadmap%20-%20theme%205%20The%20Adaptive%20School.cmap

Figures 154, 155, 156, 157, 158 show how the same roadmap theme was modelled in Conzilla (Naeve & Kamtsiou 2013).

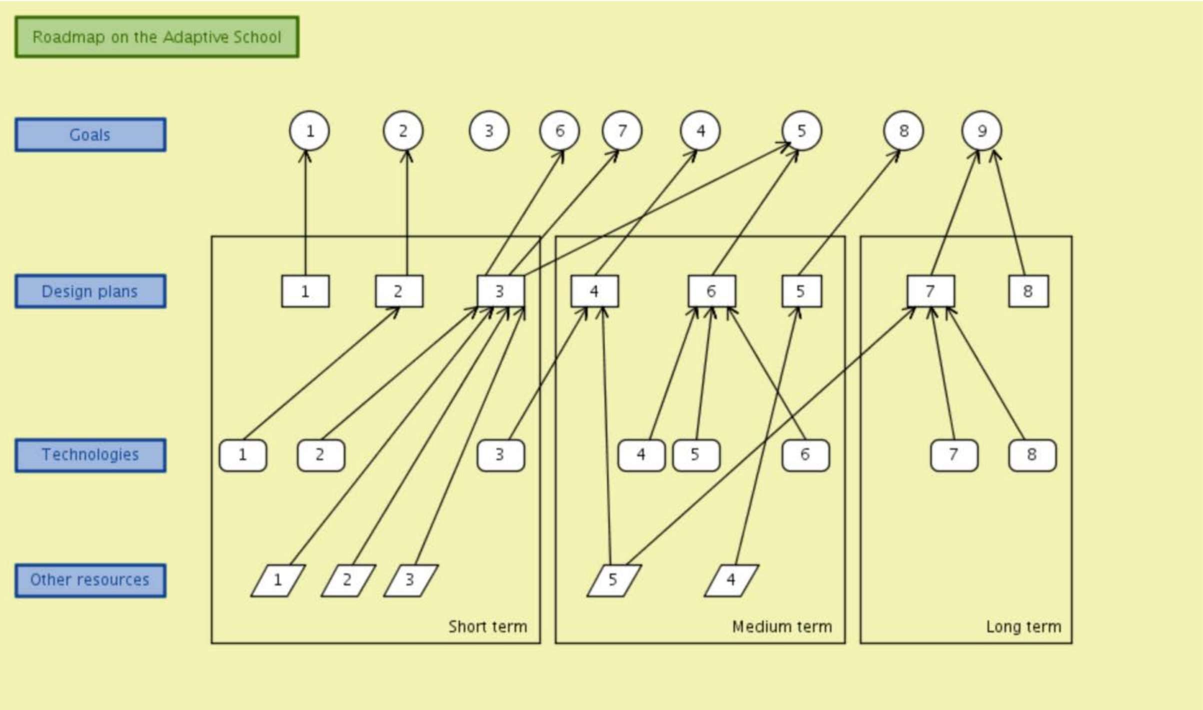


Figure 154. Initial Conzilla map Roadmap on the Adaptive School.

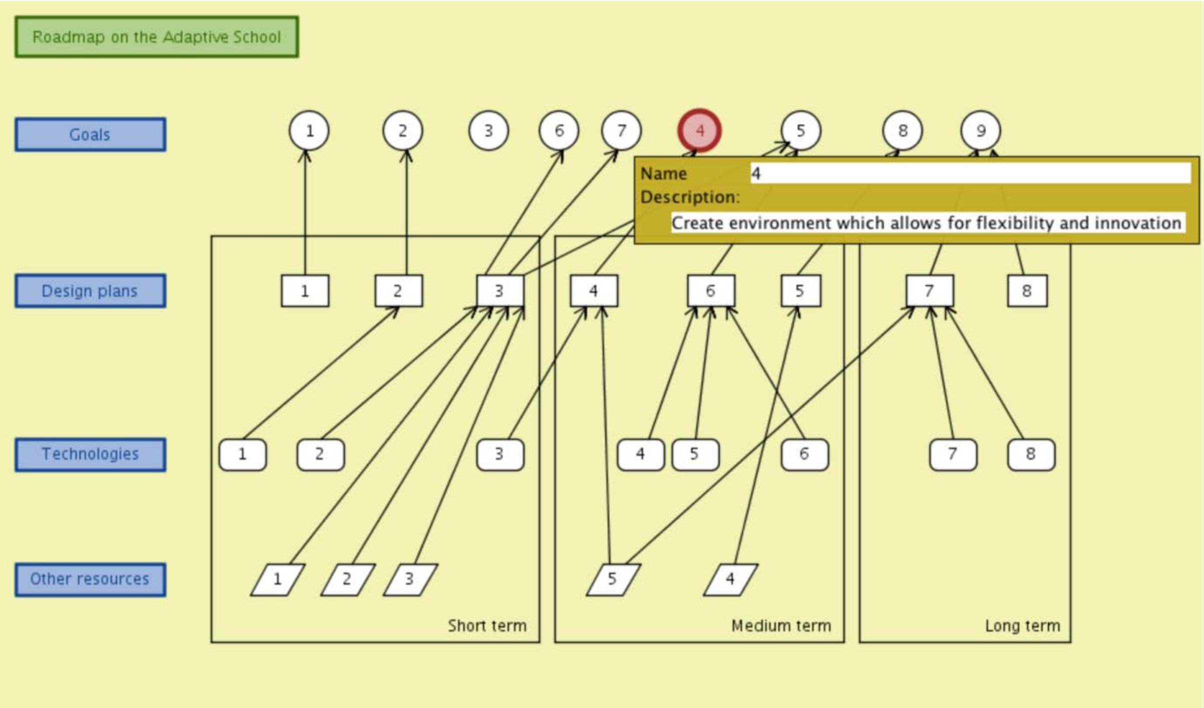


Figure 155. Initial Conzilla map Roadmap on the Adaptive School: example of Goal 4 metadata

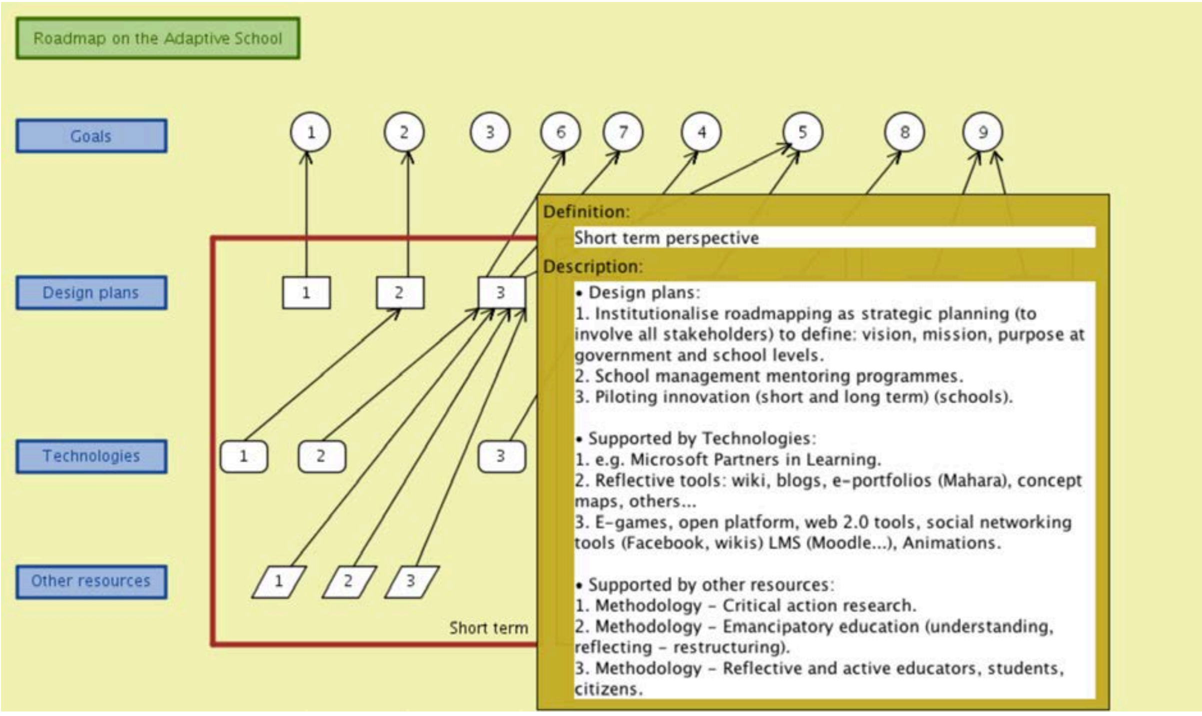


Figure 156. Initial Conzilla map Roadmap on the Adaptive School: Short term perspective metadata descriptions of short term perspectives.

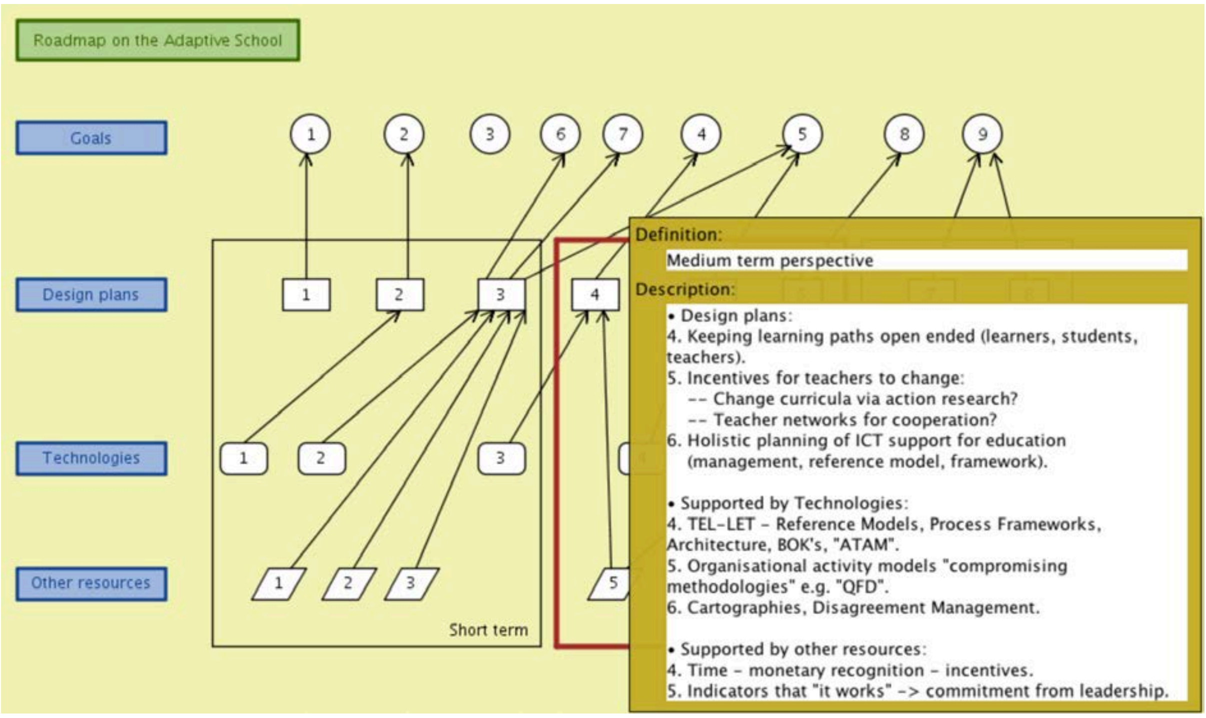


Figure 157. Initial Conzilla map Roadmap on the Adaptive School: Medium term perspective descriptions

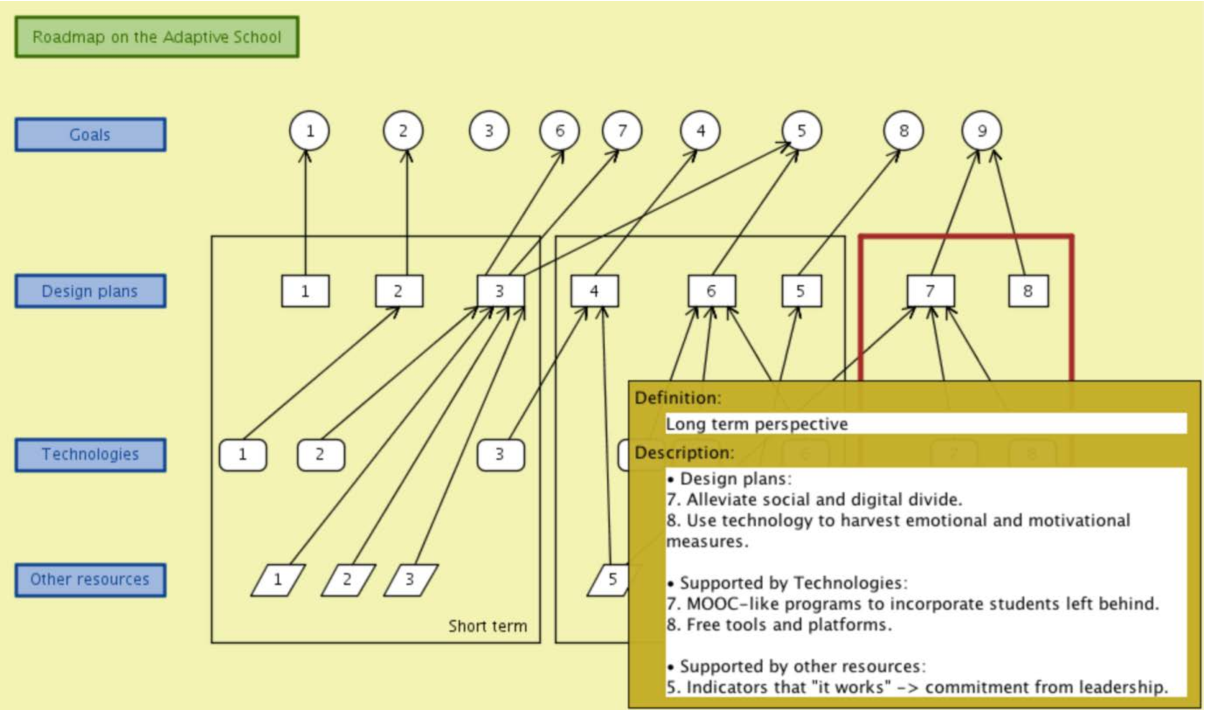


Figure 158. Roadmap on the Adaptive School: Medium term perspective descriptions Long term plans

Prior the workshop

Prior to the workshop, TEL-Map team has identified a number of research projects that could be of interest for the co-innovation group. A survey was carried out involving all TEL Unit and EAC projects. After this, the most relevant research projects were asked to join the co-innovation group and the workshop.

6.5.5 Workshop 5: Stress testing the initial roadmaps against the context scenarios and preparing innovation value blueprints

Prior the workshop

Initial stress-testing of the roadmaps using the observatory intelligence

During this step, the observatory intelligence team used the intelligence gathered in horizon scanning, weak signal analysis, SWOT analysis, gap analysis and Delphi processes in order to provide an initial stress-testing of the co-innovation roadmaps and assess their market relevance and chances for adoption (see also sections 6.3.3 & 7.3). The observatory team provided a state of the art analysis of TEL, technology assessment and a gap analysis (Giorgini et al. 2013) based on each roadmap theme. Each Theme was classified according to its potential relation or dependency from technology. The team identified the learning and educational technologies trends in the research, practice and industry and estimated their maturity assessment in terms of time for adoption, opportunities and risks. In addition, the desired scenarios and themes developed by the co-innovation group were summarised and have been compared with the technology trends extracted from research and analysts' reports. An analysis of weak signals that could affect the co-innovation Roadmaps' adoption in relation to PESLT perspectives was done via a Delphi study. The aim of these activities was to uncover the gaps between a) the desired future and technology solutions in the co-innovation roadmaps and b) the possible future according to market analysis of technologies and the contextual PESTLE perspectives. In this way, each technology or resource mentioned in the roadmaps and their themes was monitored and analysed, and related links to the various observatory reports, and web content were added directly to the Cmap models (see examples in Figures 159 and 160 below). Recommendations were also provided to the co-innovation group in the form of reports (Giorgini et al. 2013), (Wild, Lefrere, Millwood, et al. 2013), (Voigt et al. 2012).

The co-innovation group reviewed their initial roadmap and adjusted and refined the words used added or deleted features as necessary in the light of the observatory intelligence and recommendations. This was done through online Skype meetings with each of the theme groups, who discussed this input and updated their theme's roadmaps.

Figures 159 depict an example of how suggestions from the observatory were linked directly to the CmapTools roadmaps. Figure 160 shows how related content (e.g. on suggestion 'Mahara') was linked directly to Cmap roadmap.

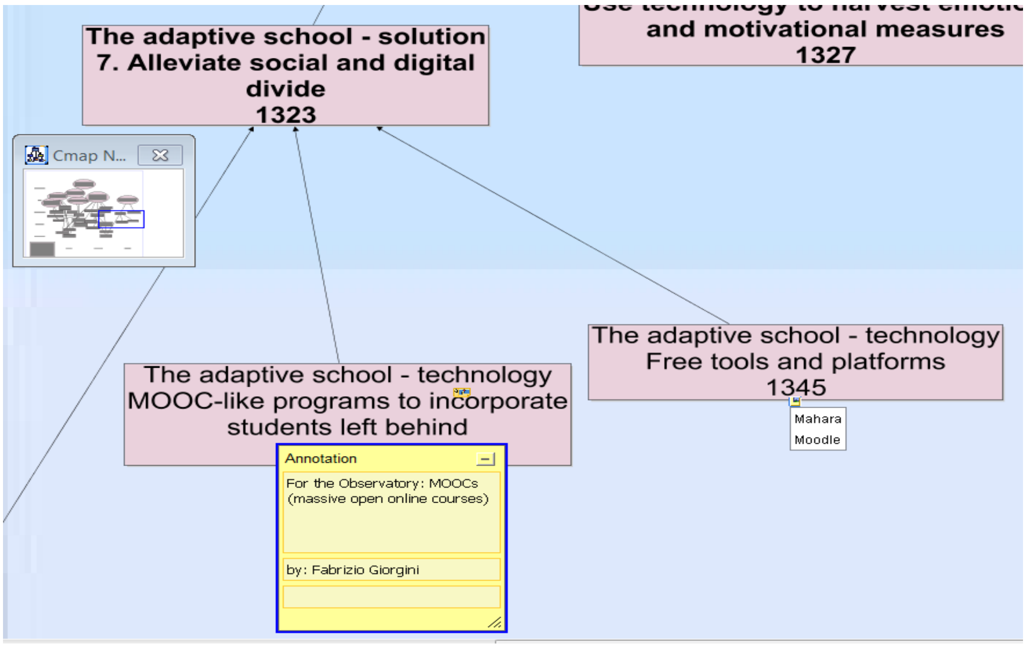


Figure 159: Annotations types to the Cmap 'The Adaptive School roadmap. A link to the observatory where the MOOC technology is monitored and assessed is provided at the solution 'technology MOOC-like programs to incorporate students left behind'. Technology suggestions 'Mahara and Moodle' were provided to 'Free tools and platforms' solution.

Figure 160. Direct web link for comment Mahara that can be accessed directly from the Cmap.

Finally, the co-innovation participants were also asked to identify opportunities for their organisation/project in the Shared Desired visions and roadmaps.

Stress-testing of co-innovation roadmaps during the workshop

Participants: facilitation team, co-innovation group, observatory intelligence team and other TEL stakeholders.

This workshop was organised within a larger strategic event called the *"European Forum on Learning Futures and Innovation"*, which was jointly organised by the TEL-Map, VISIR, and Open Discovery Space projects with the support of the European Commission (DG CONNECT and DG EAC) and the Committee of the Regions and was chaired by the author[43] (Kamtsiou & Nascimbeni 2013). This was a two days event which took place in Brussels in 18-19 of March 2013, at the Committee of the Regions.

The workshop had three main objectives. *First*, to inform education stakeholders about developments and trends that could affect their future strategic plans; s*econd*, to discuss and share e-learning perspectives and visions to foster innovation management and mainstreaming; *third*, to mainstream existing e-learning grassroots innovation practices, increasing awareness about opportunities for scalability and community building. The co-innovation group had an opportunity to validate its roadmaps and their respective contexts with a wider base of stakeholders and expand its members.

Aims of the co-innovation workshop

- Continue the ongoing cartography activities for TEL in order to enhance/validate the co-innovation's desired scenarios and contexts

[43] http://visir-network.eu/events/european-forum-on-learning-futures-and-innovation/ .

- *Stress test* their current roadmaps against plausible futures using the context scenarios (integrating roadmapping and foresight methods)
- Review the Co-Innovation Group Membership and Create the Value Blueprints for the roadmap's adoption.

Steps and templates used during the workshop

Session one: Ongoing Cartography – topics, issues, and tensions

Participants were invited to raise topics (issues, aspirations, ideas, and disputes) that they felt were important for the TEL and education: the aim was to discover the different perspectives held by the invited stakeholders and to map these. Participants were invited to step forward with an offer to lead a discussion on a topic and briefly say why it they thought it was important. Once the issues had been collected, participants chose which discussions to join. Each discussion attempted to clarify the importance of the topic, its features, and its contexts, associated tensions and disagreements and surface underlying beliefs & assumptions. The results were recorded on flip charts, and were discussed in a follow up modelling session afterwards, which produced a summary. Later models were transferred to Conzilla.

The results of the themes are summarised in the two Conzilla maps (see Figures 161, 162) below:

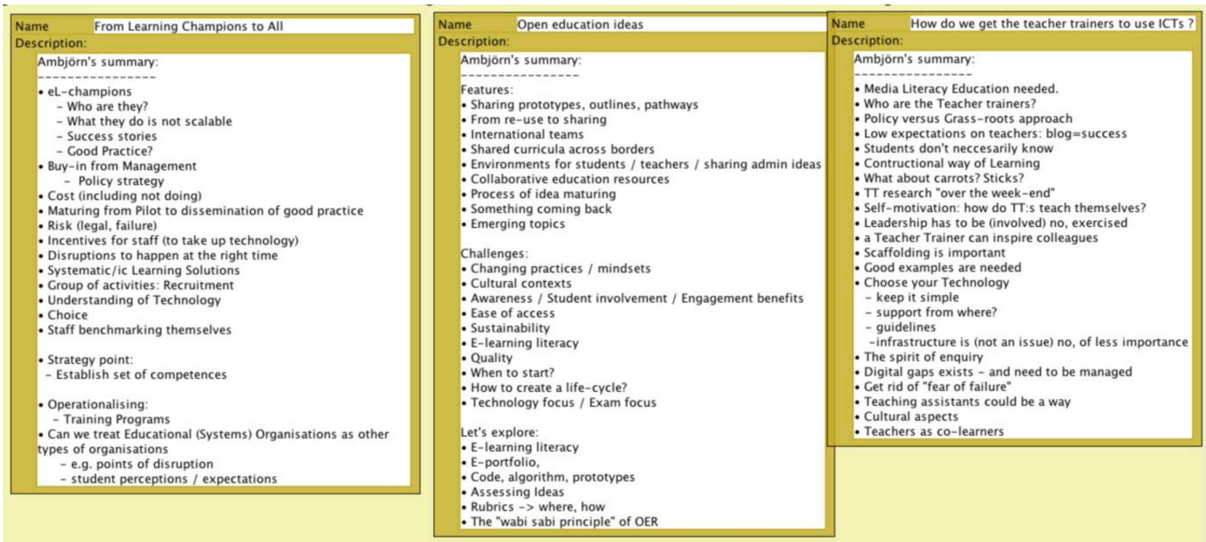


Figure 161. Results from cartography modelling (a)

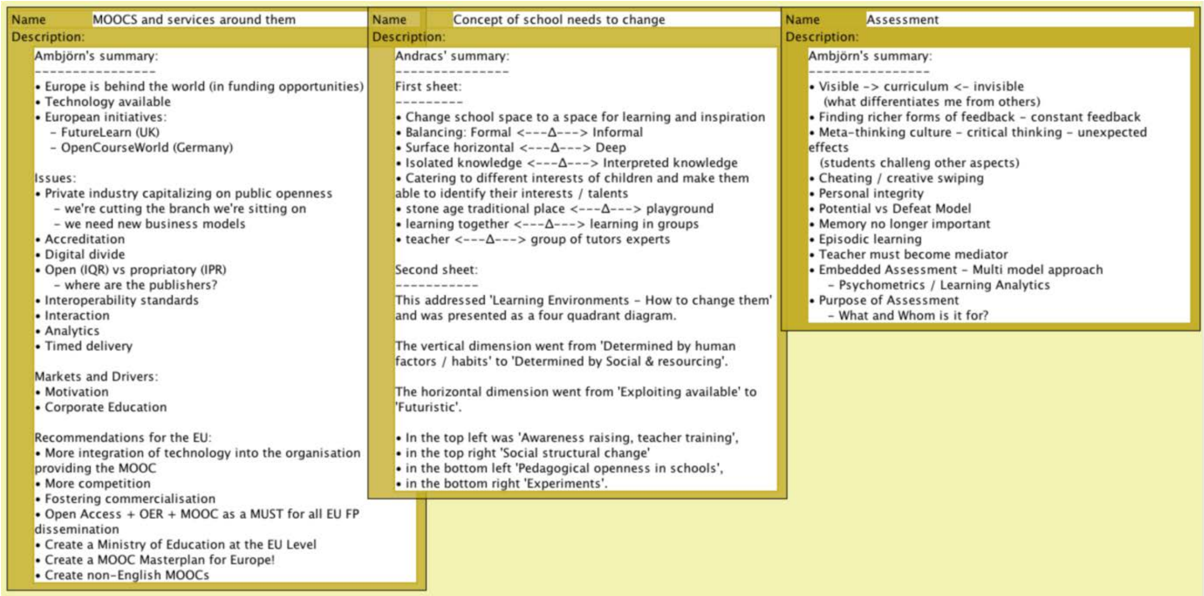


Figure 162.Results from cartography modelling (b)

Session two: stress-testing the roadmaps using the 4 context scenarios

The aim of this session was to determine whether the first-cut roadmaps needed to be adapted in order to operate successfully in different wider contexts. The four contexts were used for this analysis: a) “a thousand flowers blooming”, b) “educational Olympics”, c) “regulated safety net”, and d) “many children left behind”. These contexts corresponded to the four context scenarios derived from the second workshop (see Figure 141).
Within these contexts, different dimensions of tension have been identified. These tensions related to open issues that could impact the future contexts of schools’ education and the adoption of the roadmaps. For example, “funding could become more or less generous in the future”. Such possibility could mean different things to private schools for example, which usually are relaying on high tuition fees from public schools, which are more relaying on public funding. Moreover, such tensions, usually also reflect the power structures among the stakeholders involved, and who has the more power to influence them.

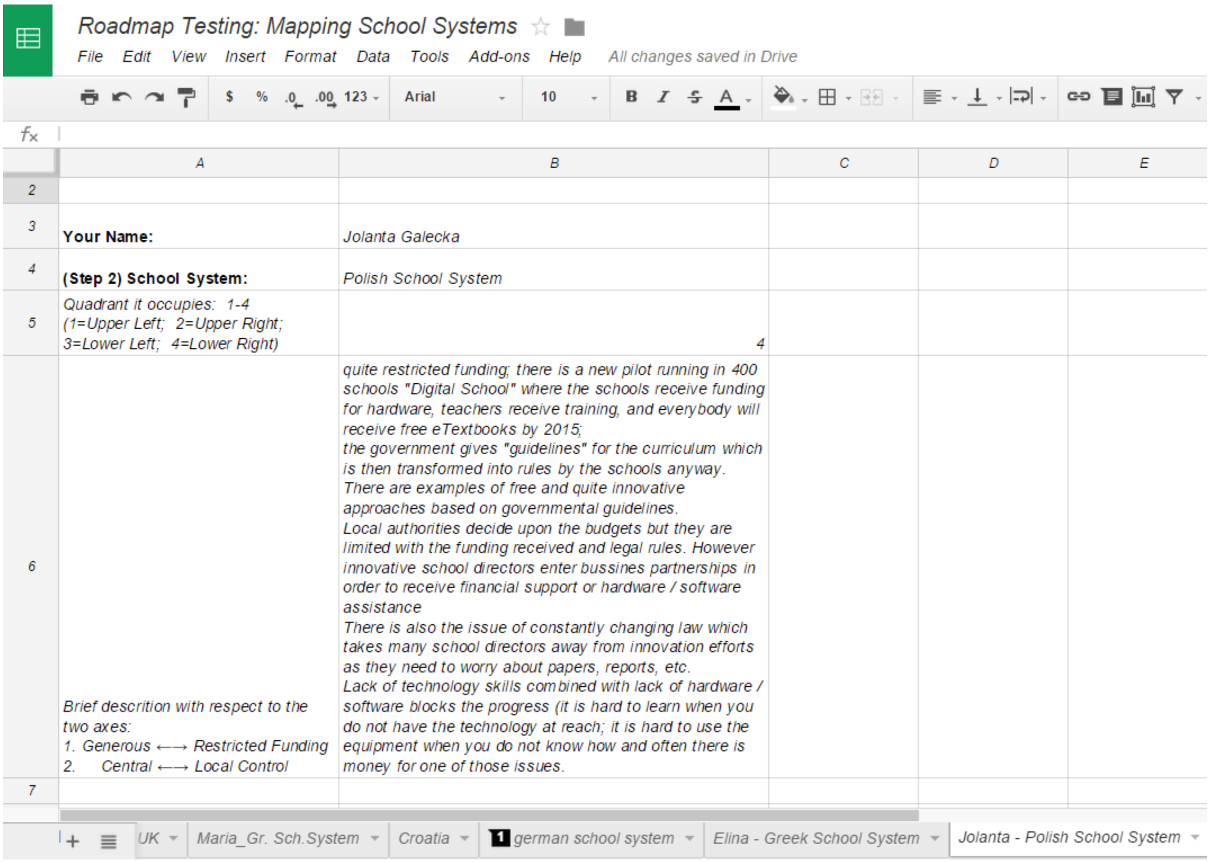
The co-innovation group recognised the diversity of educational provision across Europe and that every adoption programme for the creative learning environment (creative classroom) would have a different starting point according the given educational system and the local cultural, political, and economic circumstances. To accommodate this, they re-used their context scenario matrix as a framework for mapping the starting context for different educational systems.

The participants were asked to:

- To consider the educational system, or systems, that they were familiar with and position them on the matrix. They were asked to provide a brief description for the basis for their decision.

- Form groups based on the quadrant they placed ‘their school system in.
- Then, they asked them whether they thought the positions were static or undergoing change. Where they saw change, they were asked to indicate the direction of change by adding an arrow. Given the roadmap solutions and its initial position in the four quadrants, do they expect its position to change over the next few years (Y/N)?
    - If “Yes”, and they expect it to change, indicate the direction or possible directions? Or, if you see it moving to another quadrant, indicate which. What impact does this future have on the roadmap/s?
    - If “No”, can they identify two other major, high impact drivers which could go in either of two directions? Please sketch these out as axes, creating a new quadrant. This will form the basis for future work, repeating the above.

The participants worked in a Google template to position their National education systems for the school sector (see template in Figure 163 below).


Roadmap Testing: Mapping School Systems

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

	A	B	C	D	E
2					
3	Your Name:	Jolanta Galecka			
4	(Step 2) School System:	Polish School System			
5	Quadrant it occupies: 1-4 (1=Upper Left; 2=Upper Right; 3=Lower Left; 4=Lower Right)	4			
6	Brief descrition with respect to the two axes: 1. Generous ⟷ Restricted Funding 2. Central ⟷ Local Control	quite restricted funding; there is a new pilot running in 400 schools "Digital School" where the schools receive funding for hardware, teachers receive training, and everybody will receive free eTextbooks by 2015; the government gives "guidelines" for the curriculum which is then transformed into rules by the schools anyway. There are examples of free and quite innovative approaches based on governmental guidelines. Local authorities decide upon the budgets but they are limited with the funding received and legal rules. However innovative school directors enter bussines partnerships in order to receive financial support or hardware / software assistance There is also the issue of constantly changing law which takes many school directors away from innovation efforts as they need to worry about papers, reports, etc. Lack of technology skills combined with lack of hardware / software blocks the progress (it is hard to learn when you do not have the technology at reach; it is hard to use the equipment when you do not know how and often there is money for one of those issues.			
7					

UK | Maria_Gr. Sch.System | Croatia | german school system | Elina - Greek School System | Jolanta - Polish School System

Figure 163. Mapping the School Systems in Google document template, Polish School system answer. (Brussels x)

The following matrix was the result (see Figure 164 below).

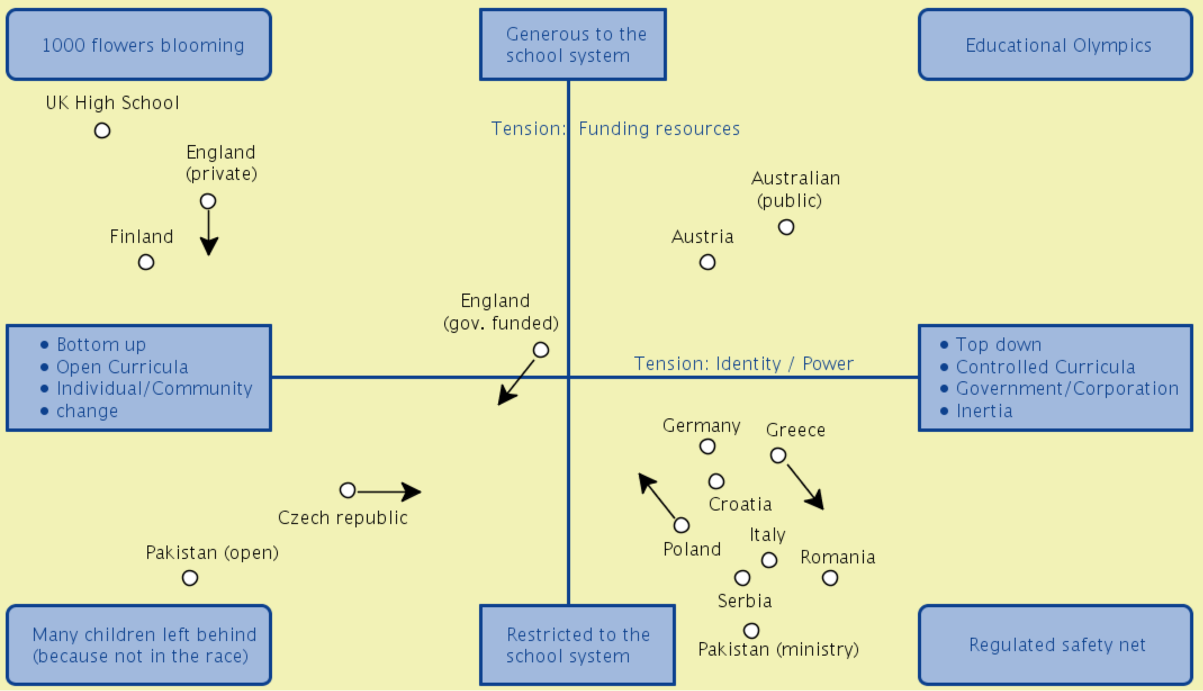


Figure 164. Conzilla map example of TEL-Map scenario matrix (Naeve & Kamtsiou 2013)

Session three: Mapping the co-innovation system and creating the roadmaps value blueprints for their adoption

During this session the co-innovation roadmaps were pinned in flipchart boards and the participants chose, which of the roadmap they wanted to work with, based on their interests and expertise. For example see Figures 165and 166 below.

Figure 165. Participants working around co-innovation roadmaps

Figure 166. Participants working around co-innovation roadmaps

Then they mapped the complete set of the players that would be necessary to successfully implement the roadmap solutions. The Adner's approach was adopted during this session in order to identify the dependences an innovator will often have on co-innovators and also the value chain suppliers and intermediaries. These players and their interdependencies were mapped in a 'value print' for example, Producers (Co-innovators and Value Chain Intermediaries) and Adopters (Decision Makers and Users).

Steps and templates used in this session

The Co-Innovation Ecosystem maps were constructed according to the Ron Adner's "Wide Lens" method (Adner 2012).

The participants followed the following adapted steps from Adner's model value blueprints:

1. *Identify your end user(s) / adopter(s).*
   - Who is the final beneficiary of your value proposition?
   - Who has to adopt our innovation for us to call it a success?

2. *Identify your own project.*
   - What do we need to deliver?

3. *Identify your suppliers.*
   - What inputs will we need?

- Who from?

4. *Identify your intermediaries.*
    - *Who do we pass our innovation on to?*
    - *Who do they pass it on to on the way to the end user/adopter?*

5. *Identify your complementary/co-innovators.*

6. *For each intermediary, ask:*
   Does anything else need to happen before this intermediary can adopt the offer, add value and move it on?

7. *Creating the Ecosystem Map or 'Value Blueprint'.*
   How do the participants all relate? What are the co-innovation value chains and decision making dependencies between them? Create a separate graph showing their relationships - use either: Paper, C-Map, or Google Drawing.

8. *Mapping the Risks*
   Identify the risks in the ecosystem. For every element on the map, ask: What level of co-innovation risk does this element present? How able are they to undertake the required activity? What level of adoption risk does this element present? How willing are they to undertake this activity?

   Assign a traffic light for co-innovation risk:

   • Green = they are ready and in place
   • Yellow = not in place yet, but have a plan, maybe late but should get there
   • Red = not in place and no plan to get there. They have blocks and are a block.

   Assign a traffic light for adoption risk:

   • Green = they are eager to participate and clear benefits
   • Yellow = neutral but open to persuasion
   • Red = prefer the status quo and not participate – as it stands

   Turn all the traffic lights green.

   With every partner that is not green:
   • Seek to fully understand the cause
   • Work to identify a viable solution

Figures 167 and 168 show two examples blue prints corresponding to *'assessment'* and *'learning to be a change maker'* Roadmaps. For example, as show in the assessment theme, the colours show that the players providing the needed technologies and the end users were ready, but the risks concerning data security and quality assurance were hindering policy makers and assessment agencies respectively making decisions that required an extensive integration of new assessment methods into the school system. School administrators, data security suppliers and parents were seen as being neutral or of mixed views, but open to persuasion. This suggested that certain actions needed to be taken if the innovations are to succeed. The red traffic lights highlight that the critical players are the policy makers and Quality Assurance Agencies. If their concerns are not adequately addressed they can become the roadblocks to the success of the roadmaps implementation. Therefore actions should be planned, such as working with the data security providers together with the policy makers and practitioners and researchers/developers in order to frame adequate security solutions. Similarly, the quality assurance agencies need both policy directives and a clear understanding of what the assessment of creative learning will entail and what would be reliable methods of assessment. School administrators would need to be convinced that new assessment methods and software, tools, can be seamlessly integrated, teacher training will be provided, and that the required resources will be available. With regards to the parents, it was suggested that campaigns to explain the need, the program and the benefits of creative learning, along the lines of industry's need for more creative people; how the creative learning environment will strongly develop this; new forms of assessment will enable students to demonstrate their new skills; and enhanced opportunities for students to have rewarding jobs in future industries. In all cases, some success stories and examples from beacon schools, which can also act as mentors, would be helpful in illustrating realistic possibilities. However, the overriding factor would be a clearly stated demand from industry, coupled with clear policy directives will be a key factor to helping turn all lights to green.

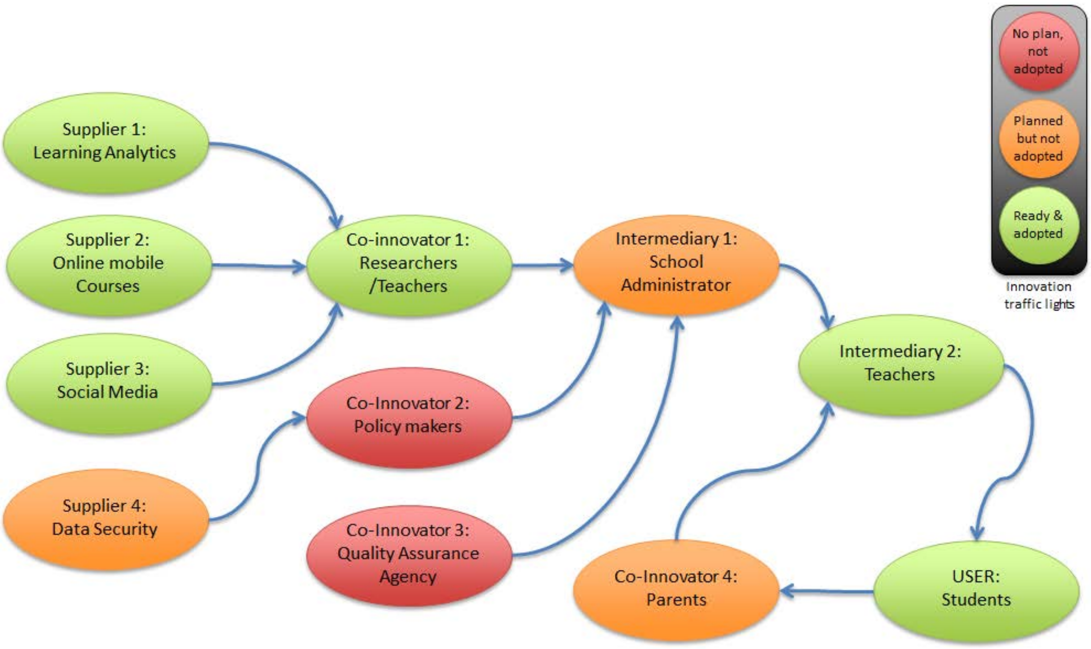


Figure 447. Assessment value blueprints

Related to the 'learning to be a change maker theme', addressing real world problems in education is currently being reserved only for specific subjects, like religious education etc. And even in those few subjects, students in most cases only learn the facts about real world problems, rather than working on a plan how to solve them. This means that the whole educational system needs to change its focus to truly achieve this vision. Schools and universities need to work together with public institutions and build also virtual networks to facilitate the collaboration. New types of pedagogies based on action research and emancipatory action research need to be developed that would provide a learning process of empowerment for the participants. Such process will enable them to take actions and make changes, based on critical reflection and an in-depth understanding on social contexts. The current roles of teacher and students in schools education do not allow for the formation of such pedagogies.

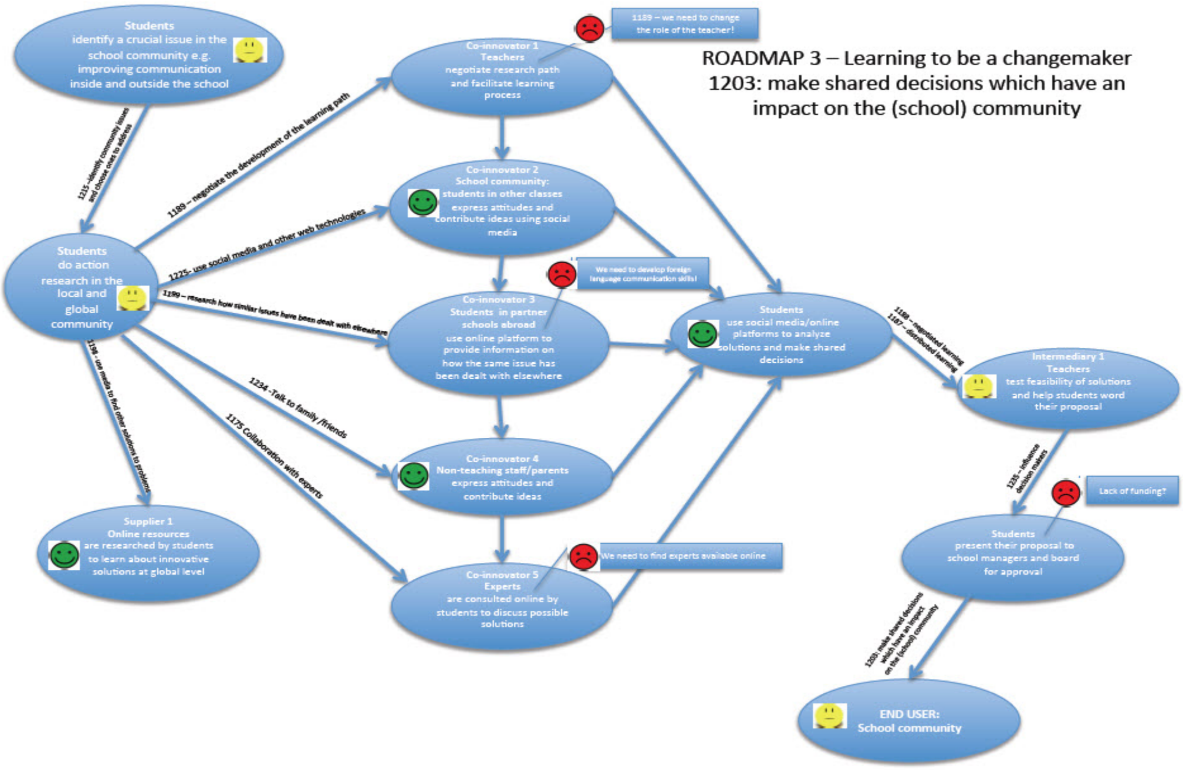


Figure 168. Learning to be a change maker blueprint

Session four: Enhance co-innovation membership and validate the 'Dynamic Roadmapping' approach

Aims of the session

- Review and enhance the co-innovation membership and plan for online activities
- Validate the 'Dynamic Roadmapping' approach and plan forward

Under the first task, the co-innovation group review their membership in order to ensure that they have all the stakeholders they will need in order to start implementing their roadmaps. The stakeholders in the workshop were also invited to participate in the co-innovation group. Discussions were also followed with the policy stakeholders from the commission about the basic functions of the co-innovation group, such as the domain cartography, the foresight and roadmapping activities and related funding support from the Commission. The discussions were recorded in minutes and a report from the event was shared with everyone later.

The second task is discussed more in detail in the conclusions section.

Work after the event

The co-innovation members together with the roadmapping facilitation team engaged in online skype meetings in order to further work on the blueprints and update the roadmaps accordingly (Giorgini et al. 2013).

6.5.6 Conclusions specific to creative classroom theme

The conclusions drawn are first that the original concept of the *'creative classroom'* is more complex than it first appears: the need is more complex and more urgent; and both its development and adoption is complex. The drivers for it seem clear (including the economic necessity of individuals to innovate; think out of the box; be able to develop and combine new knowledge and creative solutions; demonstrate their skills and competencies, and quickly gain new) if Europe is to successfully compete in the globalized economy. However the school systems across Europe are largely oriented towards the teaching and learning of existing knowledge using the same traditional classroom based pedagogies which diminish rather than enhances creativity in students. The school systems need to change if they are to meet the needs of their communities and the new demands being generated by the rapid changes in their societies. Then the question is how. Again it seems clear, the means are to hand: there is the game changing impact on both social and economic life of the Internet, the web and social media, demonstrating high levels of innovation and creativity. Integrating this into the classroom will provide the tools for the creative classroom transformation.

The theme itself also proved to be more complex. As discussed, the participants changed the title from 'creative classroom' to 'creative learning environment'. This was based on their recognition that neither the issues nor the process of producing creative solutions to them could be confined to the classroom. The new kinds of creativity that were needed had to be exercised and developed in the context of dealing with real-world problems lying in the wider communities beyond the classroom. It meant social engagement and emancipatory action research approaches based in determining tractable issues, in framing solutions and in implementing them. It would require teamwork and a wide range of both traditional and new knowledge and capabilities.

At the same time, they saw that the role of IT would need to be extended beyond classroom-based creativity. This new, wider context for creativity would in turn require that any supporting technology would also have to take on a new role of facilitating the communications needed to bridge and manage a new set of relationships between the school and external communities in which it is embedded. While a number of existing systems can be adopted, they may well need to be adapted, in combination with development of new practices, and these will demand their own creativity and innovation and the close collaboration of developers and leading edge practitioners.

They also recognized that, in order to introduce these kinds of changes it would in turn demand a range of systemic changes in the school system. Curriculum could no longer be fixed and governed top-down, but it would need to be developed bottom-up from what is valued as learning by diverse type of communities and by the students themselves. Students would have to combine and choose curricula according to their personal leaning needs and not from forced uniform regime. Existing assessment regimes would face significant challenges, including how to assess creativity and innovation, and how to do this when people are working in teams. Addressing these kinds of question would then need the involvement of departments of education, whether at national, regional or local levels, as well as quite independent exam boards.

It would also demand changes in the operation and possibly the structure of schools as new ways of teaching and working are introduced. But such transitions require support. Before any creative learning environment programmes can be rolled out, support needs to be provided to schools and practitioners already moving in this direction so that they can co-innovate with researchers, developers and supportive authorities in order to create and offer evidence-based practices, demonstrate good working local relationships and co-develop the supporting technologies. These are necessary to inform wider programmes and provide beacon or lighthouse schools that others can learn from and adapt their example to their own circumstances.

And lastly, they recognized, as they engaged in the more detailed roadmapping, that the educational systems across the EU, and even within individual countries, are very varied. That meant that their roadmaps, already extended with alternative routes to different possible futures, would also have to be adapted to take full account of different current starting points, perhaps with new and different future context scenarios that take appropriate account of the different economic, social and political forces acting in each context.

Many interesting and potentially valuable innovations for education that make use of ICT have failed to get significant adoption. The co-innovation group saw two aspects to this. One is that many such innovations are not stand-alone, but depend on one or more other suppliers to make appropriate changes also – the supply side is complex. The other is that, on the educational side, the innovation may not meet the needs or requirements of one or more of the players involved, meaning that for them there is a negative cost benefit, resulting in a block to adoption. The adopter side is also complex. Failure to recognize this complexity on both sides, and to work with it constructively, may well be a reason for the failure of many promising educational ICT-based innovations. More generally, this case study illustrates the significant problems faced when attempting to roll out innovations, even when addressing well founded needs, from a successful pilot to mainstream adoption, if it is addressed to a complex system, such as education. This then brings us to the next significant finding of the study: a solution can be provided to this type of problem. When seeking to mainstream a complex innovation to a complex system, a new, wider and more systemic approach is needed, and this is what this research work has been working towards, building on a number of previous roadmapping programmes, integrating them with several other approaches, and developing them further. This approach views the whole field in which the innovation takes place as a system; it seeks to identify key players necessary to the adoption of the innovation; any such approach needs that targets meso-level roadmapping has to integrate foresight, some form of systemic co-innovation roadmapping and an adaptive approach to innovation adoption management. These are critical factors to increasing the likelihood of success. In addition, the more complex the systemic innovation, the longer its adoption will take; and the longer in time the innovation path, the more important the dynamic and adaptive aspects become.

Moreover, such innovations are radical (if not disruptive) and therefore, there is a natural resistance from the establish systems to innovation, and this increases the more systemic and the larger the scale of the innovation. Therefore a reliable and adaptive process for reducing the risks of agreeing and implementing innovations, and involving multiple rather than individual players, will encourage people to be more innovative and more confident of putting in place the type and scale of changes that current circumstances demand.

The diversity of research communities involved in TEL calls for a broad and general approach that supports better knowledge management of research results. This means for example that Roadmapping activities need to focus on fostering greater collaboration across research communities to the benefit of all concerned stakeholders. As result, a high visible TEL cartography is an effective approach aiming to make TEL research more relevant to the society. Such cartography would include both the stakeholder that we want to engage and the different top-down and bottom-up perspectives that are needed and as well as a higher level of dissemination and visibility required to reach the desired impact. It would help to research on the role of technology as support on the educational process, broadly addressing the problems of educational research in relation to the lack of cumulativeness, presence of fragmentations; lack of dissemination, rigour and quality. Furthermore, it would be able to represent current initiatives in the TEL field as a conceptual mapping in a dynamic way, including existing research efforts on TEL with a button up perspective.

A federation of efforts at European level in order to support the adoption and scale-up of TEL roadmaps

All the Co-innovation participants agreed that a federation of efforts supported by the ‘Dynamic Roadmapping’ framework is needed in order to coordinate the efforts of the different innovative communities in Europe.

The benefits of such federation are listed below:

- Provide a process and an innovation management system for collaboration among existing innovative communities and stakeholders (e.g. researchers, learners, innovators, vendors, teachers, educational publishers, examination bodies, academic partnership groups, learning organisations, ministries, learning organizations, policy makers etc.), where new TEL ideas and applications can be discussed, piloted, exploited.

- Provide a disagreement management approach that captures the voices of TEL communities in Europe. Support the coexistence of multiple points of view and allow different stakeholders to become involved and to discuss their individual points of view in a way that does not enforce an artificial consensus or assume that stakeholders will agree on a single point of view and then collaborate on shared goals.

- Support the concentration of networks of innovative communities to produce TEL Roadmaps based on shared visions, existing goals, and contexts, and coordinates their actions for implementation.

- Alert and inform the innovative communities about developments that can affect their future plans. Provide different intelligent streams such as trends, PESTLE drivers, future contexts and signals to TEL communities, in order to anticipate and plan for shifts in the roadmaps' contexts.

- Share and publicise processes- methods-tools.

- Support the development of the research capacities in connection to the TEL desired futures and technology requirements with emphasis on R&D planning and Technological innovation management and the need for multidisciplinary competencies from different fields, e.g. cognitive, pedagogical, education management, research, ICT, etc.

- Provide support to projects and stakeholders for developing recommendations for policy makers (e.g. in order to develop their TEL funding programmes). The focus of such stakeholders as funding bodies is to address and lift the most pressing barriers in TEL and on the emerging issues that might affect the strategic direction of long term planning in TEL.

- Scout bottom-up, innovative uses of ICT for learning via the direct involvement of a network of grassroots innovators.

Table 15 summarises the above suggestions and outlines key challenges involved in this case study.

Problems/key challenges Why?	**Products/services outcomes What?**	**Resources Required How?**	**Possible funding schemes Who?**
Need for 'planning the impact' of TEL through forward looking activities and collaboration in creating the TEL desired futures.	Facilitate Co-innovation 'Dynamic Roadmapping' Networks of innovative communities in TEL and education	All necessary stakeholders who collectively can bring plan and bring the innovations to adoption.	Organizational funding Funding from Policy makers and other educational associations Member of the co-innovation could bid for cross-EU funding support to initiate co-linked actions
Need for improved Policy intelligence	Drawing input from the Co-innovation roadmaps	Resources for funding:	The Commission or other governmental funding body

	(Desired futures, roadmaps, and contexts) And from the observatory cartography, in order to inform: a) future funding plans b) near term TEL adoption plans	Planning and organising co-innovations workshops and online activities. Policy Foresight activities Observatory infrastructure and tools	diverts a percentage of its funding for 'Pull Through' support for the co-innovation and Observatory intelligent network activities European Commission; National governments; Member(s) of a federation could bid for cross-EU programmes that support horizontal capacities building via observatory functions
Need to Increase the large scale impact of funded programmes and projects	Formation of Co-innovation networks which includes research communities; identification of potential synergies and problem areas; pool of resources of innovative communities; coordination of their efforts Adaptive Innovation implementation follow-on Innovation value blueprints	Resources for: Planning and organising workshops and online activities. Observatory infrastructure and tools Cross-community and cross-project tools such as in Libraries	As above
Need to mobilise the innovators, acting where change is actually happening.	Collect and analyse grassroots innovations at EU and National Levels	Resources for Bottom-up cartography of innovation living map	TEL sector stakeholders, TEL industry, Commission

Table 15. Suggestions for the Federation of efforts group for the development of TEL in European Schools.

Chapter 7: Discussion of findings

The work on this thesis provided new conceptual models and an integrated Process Framework in order to address urgent and current needs in the area of innovation management related to Systemic Innovations. It aspires to provide new insights on issues of applied roadmapping and advance the state of the art in roadmapping and its practice. The researcher used Action Research methodology in order to successfully develop models, process frameworks and step by step practices for the development of **3rd generation, 'Meso-Level'**, **'Dynamic Roadmaps'** via sector focused **'Co-Innovation'** groups. The new models and frameworks were validated via practical implementation (see case study in chapter 6) and had significant impact in theory and practice (see also Chapter 8).

This chapter discusses the results of the case study approach and how they relate to the research questions (see Chapter 1, section 1.5) of this thesis. Sections 7.1 and 7.2 discus how the 'meso –level' Dynamic roadmapping model and framework contributes to the development of new third generation roadmapping approaches and extends the theory and practice in innovation management. Section 7.3 discusses how the Observatory model, implemented under the case study, successfully bridged micro and macro contexts and integrated foresight approaches with roadmapping. Section 7.4 discusses the results of the key five workshops and the related challenges faced in developing meso-level roadmaps.

7.1 'Dynamic Roadmapping' as a new third generation 'Meso Level' innovation management approach

At *micro level (Company) roadmaps*, the desired future is predominally driven by market requirements and customer drivers. This typically is given at the outset, most often by senior management, and the task is to work out how to get there, thus implying a top-down linear approach to innovation. In highly complex environments, where innovation is driven by the tacit knowledge and experience of several organizations, rather than by a single company, and where the integration of emerging technologies are major factors for change, focusing on the customer views and requirements alone cannot realise the promise of such innovations. Moreover, socio –economic and political challenges such as globalisation, environmental pollution, poverty, economic and political instability and todays volatile markets and environments demand for collaborative synergetic relationships among several organisations in order to respond to these challenges. A more collaborative, participatory approach is needed in order to identify and negotiate the individual visions of all actors involved in the system and to develop shared and coherent perspectives for the future.

At *macro-level*, the *industry or sector roadmapping* approach often seems to be driven by anticipated technology developments, and environmental changes, a method very close to foresight approaches. This is done through extensive use of exploratory scenarios, as well as PESTLE and impact analysis of trends that could affect the industry in the longer term, aiming to provide a detailed analysis of alternative technologies and recommendations for future R&D to develop selected technologies. It is also predominately top-down driven by experts' opinions and political agendas. But although, a good understanding of the possible technology paths and the associated drivers, whether economical, business or social, is achieved, they are often lack the exploitation of these ideas at operational levels. In the majority of cases, these types of roadmaps are usually developed by a group of experts driven by positive technology focused approaches within the comfort zone of the technical community. Often, they remain in the form of reference documents or advised actions, sometimes resulting in the development of new industry standards or to be included in policy funding programmes. The actual stakeholders' requirements are often overlooked and the roadmap remains an academic exercise or a policy reference paper (Strauss & Radnor 2004).

Dynamic Roadmapping is a new 'third' generation roadmapping approach at a meso level, which compliments macro and micro level roadmapping approaches and advances the methodologies of the previous generation roadmaps. Under this type of meso level, many stakeholders have to come to an agreement on what is needed and how it should be developed and provided in a variety of different local and PESTLE contexts. The stakeholders are creating their own roadmap for themselves to follow.

Literature review demonstrates that **'Meso-Level'** roadmapping has not yet been adequately addressed by research and practice. The concept of Meso-Level roadmaps in 'Dynamic Roadmapping' approach refers to development of roadmaps for managing 'systemic innovations'. Systemic innovations are significantly different from the first, second, third and fourth innovation models (see section 2.2 & table 2), which advocate either the linear trajectories from an invention to production to the market or from a technology exploration to the market. They have broader perspectives than the business and economic goals of competitiveness and growth and they embed the need to also meet social and/or cultural needs. Therefore, in order to be meaningful, accepted and adopted, systemic innovations need to tackle significant challenges that comply with social/economic/organisational/political priorities and systems in specific contexts. Such innovations have multi-stakeholders on both providers and adopter sides of innovation.

Stakeholders in current roadmapping models are viewed as having a passive role. In best cases, only the dominant voices are taken into account. Usually Micro Level roadmaps are driven by customers' requirements, while Macro Level roadmaps are driven by experts' opinions and exploration of technological developments. Towards this perspective, the 'Dynamic Roadmapping' framework methodology seeks to overcome limitations of earlier roadmapping initiatives, where "experts" produced roadmaps that were arguably not followed by others or were rapidly outdated by changing circumstances. The political, technical, research and practice challenges are mapped out and the stakeholders are actively engaged by bringing their own motives and actions in the innovation process. Thus, innovations are linked directly to the stakeholders' communities' interests, practices, and backgrounds.

Table16 summarises the differences among the developed Meso Level 'Dynamic Roadmapping' and the current Micro and Macro Level approaches.

Meso Level roadmapping is needed not only to overcome *the linear thinking* of the previous generations of roadmaps and the challenges associated with the demanding nature of systemic innovations, but also to *bridge directions among research, policy, industry and practice*. Dynamic Roadmapping applies a *combination of foresight and roadmapping* approaches in order to offer clearer insights, especially in case of uncertainty, across a range of competing technologies or across broader social, political and economic outcomes.

	Micro &Marco based innovation models	*Dynamic Roadmapping Model (Meso Level)*
Innovation Process	Focus mainly on economic & business issues and targets. Based on a single straight line scenario (micro-company) Focus on policy development and technology assessment. Non-actionable (Macro – industry). Static, linear or/with feedback loops, progressing.	Focus on local context. Multi-dimensional. Driven by the motives, activities, innovation plans and the interplay of the communities of stakeholders. (Integration of business/economic/ social/political rules and local practices). Brings in emancipatory concerns and social aspects in addition to business and economic. Dynamic, evolving.
Process Management	Top – down management and implementation. Visions and targets coming from top management. Hierarchical (micro). Top – down management without actionable orientation. Visions and targets coming from either policy makers and/or top management technology strategy (macro). Limited organisational boundaries (micro).	Integration of Top-down and bottom-up methodologies. Collaborative process based on managing disagreements. Synergies among stakeholder's communities and interplay with different research, industry, practice and policy groups. Emergent PESTLE boundaries.
Participants	Company employees (micro). Experts (macro).	Eco-system of stakeholders, external experts (Observatory Network) and facilitators.
Outcomes	Pre-determined, final (micro and macro). No connection to social contexts.	Dynamic, evolving visions, goals & action plans. Dynamic interplay of stakeholder's interaction. Dynamic contexts and emergent systems.

Table 16: 'Differences between 'Dynamic Roadmapping' and current micro and macro innovation models

As demonstrated in literature review (Chapter 2) and from field work (Chapter 5) both foresight and roadmapping have limitations when applied alone. Foresight methodologies provide a good understanding of the possible technology paths and the associated drivers, whether economical, legal, environmental or social, but they often lack both the active formulation of new ideas and their subsequent exploitation at operational levels. A gap in foresight research and practice exists, in terms of how to translate future changes into operational decisions and actionable plans. Roadmapping on the other hand, has great merit as an approach in establishing shared targets, and concrete goals, identifying obstacles and planning solutions to overcome these obstacles. Roadmapping is a very successful action oriented approach integrating market drivers and technology trends in strategic planning. The problem is that usually it only focuses on specific technical solutions, which are predominately driven by customer needs linked to specific market opportunities, products, technologies, resources capabilities, strategies and organisational policies. Therefore, Roadmaps have been criticized for lacking analysis of socio-economic trends and social requirements, activities which are core to foresight methodologies, thus roadmapping methodologies are *not usually connected to social contexts*.

Thus an **integration of Roadmapping and Foresight approaches** is an important contribution to theory and practice of managing systemic innovations. Moreover, Dynamic Roadmapping being applied via Action Research and analysed in a case study in real contexts pays attention to **practical validation** of this work.

Dynamic Roadmapping employs Foresight in order to capture the full contexts of decisions related to anticipate future changes, and roadmapping in order to provide innovation management activities at strategic and detailed actionable tasks levels.

Additionally, the issues of uncertainties in innovation adopters' responses should focus beyond the analysis of the technological potential and supplier's deployment processes. As mentioned above, the linear thinking of traditional supply chain management is not adequate when managing systemic innovations. Dynamic Roadmapping provides a very strong link between foresight **and change management** in order to integrate both supply and demand side of thinking and also take into account the social changes that can re-shape the innovations. Therefore, a good understanding is achieved of the distributions of uncertainties across different partners and other actors involved in realising the value propositions and functional jobs of the roadmap in different contexts. This is an important contribution to open innovation models, in terms of designing and implementing practical processes to support such collaboration.

Thus, Dynamic Roadmapping framework integrates processes from foresight, action research (Future Search[44]), roadmapping and change management: i.e., conceptual modelling is used as a means for disagreement management in order to capture, negotiate, and extend the knowledge and plans of the targeted stakeholders, and their communities. Foresight methods (including scenario planning, PESTLE and weak signal analysis) are used in order to monitor

[44] *The Search Conference*, Merrelyn Emery & Ronald Purser, Jossey Bass, 1996, *Future Search*, Marvin Weisboard & Sandra Janoff, Berrett-Koehler, 2000

and contextualise the roadmapping desired futures and planned actions. Future Search is used as systemic approach in order to a) provide a historical analysis of the innovative communities' activity systems and innovation milestones and to articulate their shared desired futures; b) facilitate the development of a 'co-innovation' value network of stakeholders, who form a community of practice and agree to build a roadmap based on their desired futures and to coordinate the tasks needed for its implementation. A new 'Cartography' approach is used in order to a) overcome the 'incompleteness problem' and thus, bring all necessary stakeholders together to succeed; b) avoid a convergent thinking problem that it is only focusing on common grounds; and c) identify collaboration opportunities with compatible partners. Coupled with the Weak-Signal approach, the cartography allows for multiple futures approach, which encompasses more than the dominant voices in the field or those of stakeholders in the co-innovation group. It also provides means to deal with surprises in the future. Adoption management methodologies are used in order to identify and resolve problems stemming from interdependencies the innovators will often have other co-innovators and other value chain suppliers and intermediaries.

7.2 Contributions to theory and practice of applied roadmapping

Dynamic Roadmapping brings new insights to innovation management. In terms of theory, the researcher has used theory and methodologies already existing from many fields and provided *an integrated new approach*. The results are integrated new models and a framework for developing Meso-Level roadmaps. This new framework recognises roadmapping as a knowledge creation process and it combines two learning theories for dynamic knowledge creation, SECI and CHAT with other methodologies from systems thinking, conceptual modeling, disagreement management, foresight, roadmapping and innovation adoption.

Dynamic Roadmapping deals with innovations which are systemic in nature. Therefore, it follows a 'Systems Thinking' approach, which focuses on the complex interdependencies among various actors and other change factors, and provides a process in order to better manage the relevance and impact of such interdependencies on innovations and action plans.

This means that:

- Systemic innovations cannot stand alone, but are depended on their co-existence in a wider eco-system. For example other providers need to co-innovate for the innovations to be successfully adopted and scale; other intermediaries and decision makers might need to align their contributions for moving the innovations forward; and other users might need to change their practices in order for the innovations to be adopted. Mapping and aligning these interdependences is needed in order to deal more effectively with the innovations' adoption.
- Systemic Innovations depend on different contexts. This includes Political, Environmental, Social, Technical, Legal, Organisational, contexts. Factors of change in these contexts could impact the successful adoption and scale of the innovations.
- Mapping these contexts and the related change factors into probable future scenarios provides a better understanding of the forces and their cross-impact on the innovations. It also assists the development of alternative strategies and actions in

order to deal more effectively with the adoption of the innovations in each of the probable future scenarios. Thus, the roadmap itself is an ‘adaptive system’ where its internal elements (e.g. visions, goals, scenarios, actions, collaboration plans, which are also viewed as internal systems) and its environment (external systems) co-evolve and mutually influence each other as the actionable part of the roadmapping process starts and evolves in the future.

- Since both the system (roadmap) and its environment (external PESTLE systems) are constantly affecting each other and change, there is no such thing as one future. The future is not a progressive straight line scenario, but it evolves and it is based on both the interplay among the roadmap actors, and among the actors and their environment.

Under the above assumptions, Dynamic Roadmapping views the roadmap as being the map, but also the territory itself. It does not only represent and maps the future state, but it creates and maintains it. The future is dynamically formed via the interplay of the actions of the stakeholders themselves as their views and intensions evolve. The goals and visions are not predetermined at the outset by managers or policy makers, but are reflecting the practical concerns of the diverse stakeholders (as co-developers). They are developed and updated over the roadmapping process, thus they considered, together with their respective outcomes as moving targets. Therefore, the roadmap is managed and adjusted via the constant monitoring and analysis of the interaction of the forces, which manifest in the stakeholders' wider environments. Dynamic Roadmapping approach maps the ‘internal systems’ of the roadmap (linked via the roadmapping nodes) and the ‘external systems’ as an interplay of the activities and actions of the innovative communities and their environment. These systems are mapped via conceptual modelling and by several other techniques including: surveys, bibliometric, Social Networking Analysis, workshops, Delphi studies, stakeholders’ consultations, visionary and foresight scenarios and action plans.

Thus, Dynamic Roadmapping advocates a new ‘meso level’ innovation management approach in order to enable the collaborative process of the innovative communities, in terms of sharing, externalising, comparing, combining and integrating their and actions, while account for existing and future internal and external tensions and oppositions. The roadmapping participants will also share and therefore minimise risks associated with uncertainties in technologies and other PESTLE factors in their field that could impact the effectiveness and efficiency of their plans. Accordingly, innovation theory is extended by **bringing the intentions, visions and actions of the stakeholders** in the innovation process (meso-level). Moreover, it **brings systemic thinking** in the innovation process, by effectively deal with the multi-dimensional factors stemming from changes in the PESTLE environments and the activities of the innovative communities. In this way, the role of the actors in the innovation processes, including other political issues such as synergies, disagreements and power structures are explored, together with the investigation of PESTLE dimensions stemming from their environments.

The SECI model is used in order to facilitate the knowledge creation process in roadmapping. Systems thinking approach, Future Search, is used in order to understand our common histories, answer the question ‘where do we want to go’, and bring together all the necessary networks of interacting human activity systems to build the roadmaps and implement the innovations. CHAT- Activity theory is applied to provide insight into the questions 'where are we now' and 'where do we come from', 'what are the problems we are facing', 'who are working on what solutions' and 'who should be involved'. Foresight and Weak Signal analysis methodologies are employed to answer questions related to 'what changes are emerging that help or hinder our route' and 'what will be the impact on new innovations'. Adner's model for Adoption management answers questions related to 'who else needs to be aligned in order to achieve successful implementation'.

7.2.1 Dynamic Roadmapping as a knowledge creation process

'Dynamic Roadmapping' is a participatory action based learning process that involves iterative cycles of sharing, externalising/expanding, negotiating/combining, and reflecting via acting on new knowledge. Recognising the fact that a roadmap is not a predictive tool, but rather a tool for collaborative strategic planning, as well as a dynamic knowledge creation process for the involved innovative communities, this research work adds value to roadmapping theory and methodological approaches by achieving the following two objectives:

1) *Introduce the new concept of 'dynamic', 'agile', 'meso' level roadmapping, which will integrate and co-ordinate the knowledge and activities of innovative stakeholders' communities. It will provide them with a conceptual model and an actionable design for the development of 'Dynamic Roadmaps' with good chances for continuous updating, implementation and adoption.*
2) *Use a case study format in order to analyse the results of applying this model at the European Schools sector, so that others can follow, further validate and extend this approach.*

Participatory learning theories like Action Research, SECI and CHAT are currently gaining attention as effective methodological approaches for community development practices. The motivation behind such practices is manifold: a) planning is informed by local knowledge and contexts; b) it increases the intrinsic motivation of the participants since they feel ownership and commitment to the outcomes; c) since a diverse spectrum of stakeholders are involved in the process, it is also assumed that a broader range of interests, topics, knowledge and information, as well as broader perspectives will be involved in the planning process (Schaff & Greenwood 2003) (See also chapter 3.1,3.1.2). These approaches fit well with the objectives of the Dynamic Roadmapping concept. Dynamic Roadmapping approach seeks to support networks of '**co-innovators'** - as **'integrated knowledge networks'** of mutually dependent innovative communities, who have shared concerns in an area of interest and collectively have the resources, skills, authority, knowledge and need to plan and develop their innovations. These *innovative communities* will share a language (and models), culture (e.g. motives, goals, values, assumptions and visions), and practices (working together to develop and implement the roadmaps), which will underling their desired futures and actions.

Thus, establishing a *'community of practice*[45]*'* (Wenger & Snyder 2000) as a co-innovation group, which will be responsible for negotiating, building and implementing its roadmaps is of paramount importance.

Let's consider for example the schools domain investigated in the case study (see Chapter 6). 'Meso' level roadmapping is especially important for the schools' education sector. Literature review (Bocconi et al. 2014), (Brečko et al. 2014), (Kampylis et al. 2013), (European Commission 2013), (Nascimbeni & Kamtsiou 2014), (Meiszner et al. 2014), (Engeström et al. 2002), (Paavola et al. 2004), and the case study (see chapter 6: Section 6.5.6) suggests that TEL innovations in schools are not linear, single rooted or independent, but rather **systemic**, involving several converging and or competing technologies, complex interactions by many players, who have to collaborate in order to align their contributions and resources internally and externally and develop holistic solutions, rather than simply the introduction of new standalone products. Furthermore, TEL innovations in schools education have the potential for radical change, which transform the learning practices, the schools as institutions and the communities (e.g. teachers, students) who will adopt these innovations (Paavola et al. 2004). This transformation and expansion though is very difficult, because of various social, pedagogical, and organisational structures deeply rooted in the classroom-teaching paradigm, teacher centred learning pedagogies, the traditional isolation of the teacher's profession and political top-down governance. Transforming schools into 'creative learning environments' require several stakeholders and their communities to work together with teachers and students, in order to develop and test these innovative new models, pedagogies, visions and practices. In this respect, the Dynamic Roadmapping methodology is applied in order to support and implement such transformations, as a process that not just synthesises information, but one that supports the creation of new knowledge, value, and practices and thus, it is considered as a ***dynamic knowledge creation process*** for the innovative communities (Li & Kameoka 2003)*;* (Kamtsiou et al. 2006). It enables scheduling of common activities; structuring the discussions among their members; negotiating and representing the multiple perspectives and the associated positions in a way that can be easily understood and further developed by others; and support and coordinate the collective actions for realising and adopting the innovations. Thus, action oriented, participatory learning theories for knowledge creation can be utilised in order to organise the roadmapping activities.

Although, as stated above, these new participatory practices are gaining momentum today for the development of stakeholders' communities of practice, they still facing some important challenges: a) it is difficult to achieve an inclusive community representation of all necessary stakeholders, b) manage disagreements and power relationships within the communities, c) select the most appropriate input and topics for starting the dialogues which will drive the planning process. Below follows and analysis of how Dynamic Roadmapping successfully addresses these challenges and extends these learning theories in practice.

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[45] Wenger and Snyder is community of practice is *". . .a group of people informally bound together by shared expertise and passion for a joint enterprise"*

Dynamic Roadmapping Extends the participatory learning approaches: combining SECI and CHAT

The Dynamic Roadmapping activities are viewed as intertwined spirals that provide seed input for starting dialogues among the innovative communities. Thus, the various knowledge assets of the innovative communities are mobilized and shared in 4 different interaction spaces (Socialization, Externalization, Combination and Internalization), while the tacit knowledge held by individuals is transformed, expressed and amplified by the SECI knowledge-creation spiral (see also Chapter 3.1, 3.1.2).

Nonaka, Toyama and Konno (Nonaka et al. 2000) assume that in order for new knowledge to be created dynamically, a vision must pre-exist in an organization, which will drive and synchronise the SECI process. The creation, articulation and communication of this vision inside and outside the company are the role of top management. This is a top down hierarchical approach, which applies to a single organisation. Moreover, the authors argue that this vision will define, and determine the organization's value system, and the quality of knowledge that will be produced. It also assumes that everyone in the organization is complying and agrees with this vision. Dynamic Roadmapping, as a meso level approach, synthesises the views and visions of a number of diverse stakeholders, who do not automatically comply with a pre-shared idea of what the future state should be. Therefore, a pre-existing vision does not exists which can be the driving force for the collaborative knowledge creation process in the communities. To make sure that the conflicting interests and weak signals are observed and analysed, the roadmapping process is supported by applying aspects of the Cultural-Historical Activity Theory - CHAT and from Weak Signal Analysis.

CHAT theory provides the conceptual tools in order to understand capture and synthesise the multiple perspectives of different networks of stakeholders (innovative communities) and their respective interacting activity systems in the domain, sector or segment. In that respect, CHAT theory is used in order to: a) form the co-innovation group, i.e. bringing together shareholders based on their shared interests, (objects) and activities; b) making sure that the roadmapping methodology takes into account the stakeholders' requirements that might have been ignored by the initial co-innovation group; and c) make sure that not only the dominant views of the most influential stakeholder are taken into account.

This serves as a *bottom up mechanism*, in order to better understand and choose the strategic issues (units of analysis in the roadmap), the seed input chosen to be used as a starting point for discourse, increase the motivation of innovative communities to participate, and manage effectively any conflicting interests of these communities. The aim is to *support and strengthen networks of people that are connected by shared objects (what they investigate, produce) through common activities, tools and shared spaces* (Kamtsiou & Hoel 2009), (Kamtsiou & Klobučar 2013), (Kamtsiou & Olivier 2012).

In this light, the roadmap is also viewed *as a system that interconnects several complex interacting activity systems*[46], their networks, and outcomes (Kamtsiou & Klobučar 2013). Because of this complexity, it is very difficult to understand all the causal relationships underpinning these activity systems or even consider their outcomes (e.g. their desired futures, goals, roadmaps, new practices) as final or predictable. The outcomes, which will be developed by the innovative communities at the systemic levels of their activity systems, need to be contextualised in different social, political, economic, cultural, sectoral and organizational situations, and they need to be constantly monitored and evolve. This is because the 'objects' (purpose, motives, desired futures, goals and practices) of these communities may change, either due to new opportunities based on new technological developments, or due to surprises, tensions and contradictions, which appear in their environment. Dynamic Roadmapping approach, continuously *supports the* innovative communities *with different types of intelligences*, such as competitive, market, technology, research and policy, which helps them to monitor their roadmaps and to make informed decisions on their updates in order for the roadmaps to remain agile (see sections 6.3, 6.4, 7.2.2, 7.3 and tables 11, 12). Such intelligences also enable the innovative communities to match their diverse interests and practices in order to form a co-innovation group and later on find and invite new members to join their networks, who have shared goals and interests and the complementary skills, knowledge, resources and knowhow needed to implement the roadmap innovations and bring them to adoption and scale.

7.2.2 Integration of Weak Signals and Cartography function

In Dynamic Roadmapping framework, SECI and CHAT models were complemented with weak signal analysis in order to take into account aspects about the future (at both micro and macro levels) that might otherwise be dismissed as possible because they might not be considered attractive by the co-innovation group members. Or they might be overlooked, since they are not regularly associated with the particular sector or domain or they are in the radar of the co-innovation members.

In 'Dynamic Roadmapping framework', a weak signal is considered to have passed the *surveillance and mentality filters*, once it is captured and accepted for discussion by the observatory and/or the co-innovation group. Similarly, it is considered to have passed the *power filters*, when an analysis about its impact on the roadmap outputs (e.g. cartography, visions, scenarios, future actions) has been made. As demonstrated by the case study, the use of diverse information resources (e.g. blogs, scientific publications, social networks, analysts' reports, conferences, experts' interviews, research projects analysis etc.) during the horizon scanning activities minimised the problem of staying within our comfort zone of the *surveillance filter*. Looking for signals related to the specific challenges specified in the visions of the co-innovation group as well as to the uncertainties related in the context scenarios (*workshops 1: shared perspectives* and *2: Context scenarios*), in combination with text mining approaches, minimised the problem of *mentality filter* (information overload and

[46] Activity systems: "concept of object-oriented, collective and culturally mediated human activity, or *activity system" http://en.wikipedia.org/wiki/Activity_theory*

staying with dominant views). *Power filter* is minimised by looking at more unbiased information in the blogosphere and in scientific journals and conference papers (see sections 6.3.2). The involvement of diverse and broad-range stakeholders via both policy and practice Delphi study also helps minimised the *power filter (see section 6.3.3).* Under *practice Delphi*, the stakeholders are asked to estimate the time of occurrence and assess the impact of specific factors that might affect the innovative practices. Under *policy foresight*, the stakeholders are asked to assess the feasibility and desirability of given policy interventions. In addition, in 'Dynamic Roadmapping' approach two types of sources are used: *people sources* (experts, and other stakeholders) and *digital data sources* (recorded internet resources, such as blogs, conferences, scientific publications, surveys, etc.) (See section 6.3). The results of these two methods are cross-referenced and compared by the co-innovation group and fed back into the observatory function.

The case study explores ways to model signals, practices, differences of view and approaches in the wider TEL community and in its subsets. An example is the synergy between modelling tools and the insights from the co-innovation and observatory group activities. Modelling tools helped to model agreements and disagreements as part of analysis of a wider range of data than originally shared by the observatory, such as "weak signals" and "and capturing the voice of communities" (see sections 6.3, 7.2.2, 7.3.1, table 12).

In order to assist the co-innovation group, continuous monitoring and analysis of weak signals and respective Delphi studies were provided in the portal by the observatory network (see section 6.3.3). Additionally, the observatory was producing special periodic reports (e.g. 'Report on socio-economic developments most relevant to emerging new Learning paradigms') in order to assist the co-innovation group to use this analysis and update their roadmaps (see section 6.5.5, Workshop *5: Stress-testing initial roadmaps*). Such reports show how weak signals together with expert opinions and roadmapping efforts contribute to the identification and productive discussion of new learning paradigms in TEL. The Mediabase function of the observatory, provided tools that combined social network analysis (SNA), with topic mining analysis and informed the co-innovation group on emerging topics and issues that could affect TEL (see section 6.3.2). A more detailed analysis provided in case study section 6.3 and later in this section 7.2.2, 7.3.1)

New approach to manage agreements and disagreement: Mapping of Controversies via cartographies and weak signals.

As noted in literature review (section 2.1.6), weak signals are situated or "they lie in the ears of the listener" (Mendonça et al. 2012). They are a result of the players' interaction ('observers') within the domain of study, segment, sector, or issue at hand. They are often associated with tensions and polarities related to the interpretation of their impact and with choices taken in order to influence and deal with such impact. For example, signals that point to possible economic recession could be associated with negative effects for those depending on government spending, but with positive ones for investors who can buy things at cheaper prices. An example comes from the economic recession in UK and its impact on the Higher Education Sector. The cut in educational budgets by the Government triggered high level of uncertainty related to the viability of several Universities, while provided opportunities for others to successfully increase their tuitions substantially. Who loses and who wins is an important analysis, as well as what are the possible choices in order to deal with the effects, and the possible collaborations that will support such choices. The case study (Chapter 6) provides a good example on how the observatory network made extensive use of combined methodologies and tools to manage uncertainties and disagreements in order to support the Roadmapping process and register and make sense of the associated weak signals. These signals may come from within or the periphery of the domain of interest, or from more macro PESTLE drivers. This analysis was very important in order to support the co-innovation group to bring out the underlying assumptions (weaknesses as external influences or treats as internal warnings) in their context scenarios (workshops 1 and workshop 2), and then develop (workshop 4) and assess their complete solutions or action plans (workshop 5). Based on this analysis, chapter 8 suggests some further research that can improve the type of tools and services for building the observatory.

The Disagreement Management approach in Dynamic Roadmapping methodology was first introduced in PROLEARN Project (Kamtsiou et al. 2005) and later adopted by ICOPER (Kamtsiou & Klobučar 2013) and TEL-Map projects (Kamtsiou & Olivier 2012) and is documented in the case study. It integrates a number of methodologies such conceptual modelling, mapping of strategic conversations, cartography of disagreements, weak signals and CHAT. For example, conceptual modelling is used as a communicative modelling technique called bottom-up conceptual calibration, which is first described in (Naeve 1997) and which involves mapping the following three steps: 1) Agreeing on what we agree on; 2) Agreeing on what we don't agree on; 3) Documenting steps 1) and 2) in a way that we agree on. The great benefit from such method in comparison to top-down approaches – is the fact *that it does not aim for consensus*. Instead, *mind liked and complementary innovative communities* are brought together in order to work together in developing and implementing their roadmaps. In the case study, different modelling tools were used for supporting such discourse, developed by KMR group at the Royal Institute of Technology (KTH) in Sweden. A bottom-up conceptual calibration technique is supported by the Conzilla[47] conceptual modelling tool (Naeve 2005), (KMR group at CID 2010). Other free web-based collaborative modelling tools like CmapTools (IHMC 2014) were also used for modelling the relationships between the concepts. CHAT and cartography of controversies are used in order to provide a methodology for creating an ongoing cartography of the domain, which maps the objectives, activities and outcomes of the innovative communities and other stakeholders (see Chapter 6, section 6.3.4 modelling using the Conzilla and Confolio Tools).

Dynamic Roadmapping employed disagreement Management approaches which are linked to actor-network theory, controversies and weak signals (Venturini 2010) (Venturini 2012).

Controversy is defined by Venturini in the following way: "The word "controversy" refers here to every bit of science and technology which is not yet stabilized, closed or "black boxed" ... we use it as a general term to describe *shared uncertainty"* and as 'situations where actors *disagree* (or better, *agree on their*

[47] Conzilla conceptual browser: http://www.conzilla.org/wiki/Overview/Main

disagreement). The notion of disagreement is to be taken in the widest sense: controversies begin when actors discover that they cannot ignore each other and controversies end when actors manage to work out a solid compromise to live together. Anything between these two extremes can be called a controversy" (Venturini, 2010, p. 260-261). The cartography of controversies is based on a simplified ANT approach, which aims to identify and map the complexities of tensions in a knowledge field (Law 1998). (Venturini 2012) describes Cartography of controversies as a "set of techniques to investigate public disputes especially, but not exclusively, around techno-scientific issues" (Venturini 2010, p.2).

As a simpler version of ANT, Controversy is based on the following 3 rules (Venturini 2010):

- "you shall not restrain your observation to any single theory or methodology;
- you shall observe from as many viewpoints as possible;
- you shall listen to actors' voices more than to your own presumptions" (Venturini 2010, p.3).

Venturini stressed that following these three simple rules make the exercise of observation and mapping very difficult because of two main reasons: a) the meaning of word "just" which means that *"observation devices are the more valuable, the more they let those who are observed interfere with those who observe"(Venturini 2010, p.3);* and second, because of a second degree of objectivity that "comes from attributing to each actor a representation that fits its position and relevance in the dispute. Being proportional in social cartography means giving different visibility to different viewpoints according to, 1) their representativeness, 2) their influence, and 3) their interest" (Venturini 2010, p.5).

(Venturini 2012) stresses that influential viewpoints cannot dominate the social cartography map. He says that "Controversy mapping cannot content itself with *majority reports*, as the very rise of disputes depends on the presence of *disagreeing minorities*. It is disagreeing minorities who bring controversies into existence by refusing to settle with the mainstream and reopening the black boxes of science and technology" (Venturini 2012, p.6). Taking this hypothetical approach of controversy that is fundamental for Disagreement Management, it suggests that we should stay away from trying to figure out "what is a weak signal." Instead we should concentrate on finding out what the actors involved with the investigated Roadmapping area would consider to be weak signals, under what conditions (assumptions) they would consider something to be a weak signal, what this signal would signify to these people under what assumptions and what are their choices to deal with the effects.

"Shared uncertainty", "controversy" in Venturini papers (Venturini 2010) (Venturini 2012) is used as a general term to describe uncertainty, something that the Weak Signals (WS) are trying to address as well. The above activities described in cartography controversy are complementary and preconditions for the WS analysis.

Dynamic Roadmapping uses both approaches as observations in order to try to understand tensions. The differences come from a) what cartography and WS actually observed, and b) the kinds of tensions described. While the cartography of controversies approach describes tensions that are resulting from *the actors' power structures* (mostly internal to the system), the WS describes tensions that are coming from *external changes* that can usually be viewed as both a threat and an opportunity. Also, while cartography of controversy is focused on *today (the big picture)*, therefore, transparency, shorting out the domain, incremental change and stakeholders management are very important, WS is *focused on tomorrow*, where divergent thinking, diverse perceptions, stakeholder leadership, disruptive innovation are more important. In the 'Dynamic Roadmapping' model, cartographies and disagreement management are referred as "strategic conversations" that comprise the domain of the Roadmap (see section 6.3.4, 7.2.2, table 11, 12, 14) and are also modelled as semantic profiles for researchers, organisations, projects (see section 6.3.4, figures: 100,101,111, 112, 113, 114, 115, 116, 117, 118, 119, 120). Several workshops, interviews and Summer School sessions were organised in order to capture the voices of the communities. Weak Signals in Dynamic Roadmapping are captured by the Observatory, using technology reviews 6.3.2 and Delphi studies (see section 6.3.3) and via the co-innovation *workshops 1: shared perspectives* and *2: Context scenarios* (workshops 1, 2, 5, in respective sections 6.5.1, 6.5.2, 6.5.5)

Main principles of WS in Dynamic Roadmapping: The most important assumption is that the signal by itself is just an *event* or *information* that does not mean anything and does not have any intrinsic value by itself. According to (Coffman 1997) WS are conditions or situations, but they do not formulate specific problems or provide specific solutions. What is important *is the interpretation of the signal by the receiver,* who would bring the creativity and insight needed to formulate the problem in order to be solved or to discover the opportunity that can change the current practices. Since Foresight as a method connects/converge (via desired futures), contrast (via tensions and polarities identification), and stress-test (via exploratory scenarios) the various stakeholders Roadmaps, the interpreters of the WS in 'Dynamic Roadmapping' case are the domain stakeholders and other actors that can influence the domain. *'Controversy'* can be seen in the ways the different stakeholders and other actors interpret a WS and choose (or not choose) to act upon these interpretations, which we need to be brought up in the attention of the co-innovation group during the Roadmapping process.

Dynamic Roadmapping uses cartography as a tool in order to map an Ecosystem of actors and as a tool to map these actors' strategic conversations (see section 3.1.2, 6.3, tables 11 & 12).

While cartography is trying to deal with uncertainty by mapping out the controversies, in terms of the relevant actors, their positions and disagreements, their influence and their interests, WS provide the new information that are emerging, which can contribute to stabilizing or change this mapping (landscape), e.g. as potential innovations/disruptions or potential threats which if ignored could lead to unforeseen catastrophes.

In addition, signals were not looked only within the industry, since signals that are coming from the industry for use in the industry are shared broadly and tend to mature easily. The most valuable signals usually come from someone working outside the field, which happens to invent a solution in search of a problem, or a solution for someone else's problem.

In our 'Dynamic Roadmapping' framework, having TEL as an application, an area characterized with the high uncertainty, it is safe to assume that these kind of signals could happen also within TEL, but not within the same dominant TEL groups, but mostly probably within the minority disagreement groups, who are out there to change the status quo with ideas that often viewed as comic or virus from the dominant players. Or within the technologists/researchers, who are using developing technology solutions for Education and Training as application domains, without considering or integrating their findings with education research. Within TEL there are several types of actors with different and often conflicting agendas. For example, we have the technologists, who are interesting in investigating new technologies, and who find the learning domain a good application for these; we have the pedagogues, who are interesting in analysing old learning theories, testing them, and sometimes in developing new ones. For good reasons, quite often the pedagogues are very sceptical about the merits of technology, often regarding it as a 'necessary evil' in order to get their research funded. Usually, at European levels, these projects are funded by Education and Culture D.G., while technologists were getting funded for their projects by the TEL unit.

Moreover, we have the TEL producers, who split into commercial and non-commercial (academic, researchers). The commercial ones are driven by profits and increased sales of their offerings, while the academics are driven by number of publications. Therefore, all these actors have different goals and agendas, and if we add politicians as the type of actors driven by socio-economic changes and from their personal agendas for re-election, we can safely assume that TEL is an area of controversy. To add to this complexity, TEL conflicts are often hidden (tacit) and sometimes agreements are difficult to be achieved. Different communities are developing their own roadmapping activities, e.g. policy makers are using foresight and policy roadmaps, researchers are developing research & technology roadmaps, and commercial actors are developing company and industry roadmaps. 'Dynamic Roadmapping' integrates the different types of roadmaps developed by different communities via a co-innovation group and an observatory function (see figures 68, 121, also sections Chapter 3: Challenge C, Chapter 6: section 6.4, Chapter 7: section: 7.3).

In that respect identifying the positions and differences among these actors in the domain, helps the co-innovation group to understand and cluster the issues and drivers in the domain. Often, bias in TEL that is mostly related to the noise surrounding the interpretation of the signal is related to the underlying mental models or influential view points of the dominant players in TEL. A good example can be found in the standardization groups and research and development projects that tend to hold on standards that are no longer working or being adopted, but are still using these standards in research projects, which aim to create innovative solutions for the area. The same can be said for the TEL software and tools producers, who are still clinking in ways to re-produce traditional classroom and learning instructional models. A cartography of the agreements and disagreements in the domain is enabling for capacity building in TEL stakeholders community in Europe and help to share their insights on past and current TEL and some of their thinking in TEL futures. Thus, TEL networks can benefit from improvements in capabilities of the stronger participants in TEL, thus facilitating the spreading of TEL innovations more rapidly. Such mapping, it captures the *strategic conversations* of different TEL communities. It helps TEL stakeholders to understand and compare what is going on in other (competing or complementary) communities and how these communities value and/or intent to use the proposed solutions in the roadmaps. In this way, a bottom-up approach is achieved in bringing like minding or complementary networks together in order to start *co-innovation roadmapping networks.* In addition, such input serves as starting point in the problems and challenges for their roadmaps. The *Activity theory* is used in order to map innovative communities, who are working on the same problems while connecting them via their existing networks and tools (see section 3.1.2, figure 56 and metadata profiles in 6.3.4).

Once this landscape is mapped, the observatory network *broadcast the signals back* to the different Roadmapping co-innovation groups, so that they can encode the signals and provide their interpretations. In addition, as it was said before, no WS is able to raise to dominance by itself, but it is actually accompanied by shifts in political, economic, technological, and social thought and invention. In that respect, a connection to the PESTLE drivers is very important in order to assist us as where to look for WS and to provide us with insights for their analysis. More over, the analysis of WK is connected to the value systems, contexts and beliefs of the selected stakeholders communities that form the co-innovation roadmapping network. The complexity of interpreting a weak signal is high, since, it is related to the bias of the actual actor who interpret the signal, and to all the above mentioned associated parameters such as mental models, interests, roles, different context, conflicting agendas and tacit knowledge. For these reasons, *storytelling* is viewed as a good instrument for interpreting and analyse the potential impact of the WS and w*hat was considered in context scenarios in 'Dynamic Roadmapping' (see workshop 2 section 5.5.2).* In order to capture and analyse WS, *data mining, text mining, workshops with experts and Delphi techniques* were also employed (See Section 6.3.3, table 11).

The case study demonstrates how the Dynamic Roadmapping Observatory Function constructs a cartography *map* of the TEL domain with special emphasis on schools' sector. Such map captures, externalizes, aggregates and contrasts the views of TEL communities in order to contract an interoperability mapping as part of the TEL cartography map: Trying to make the communities to describe their activities and taken positions on TEL and reveal their assumptions as well. This methodology '*captures the voices'* of the different communities and how they see themselves and how they are perceived by external communities and TEL stakeholders. It brings up their assumptions, where they coming from and what are their positions, visions, activities and strategic plans for TEL. As described above, a cartography is created using methodologies based on dynamic modelling, bibliometric and social networking analysis techniques in order to provide a landscape for the area in terms of where capacity is building, what are the dominant beliefs and assumptions, who is doing what, using what technologies, approaches, projects, what is perceived as threat and opportunity, what are the main visions and plans of stakeholders. Metadata profiles and electronic portfolios were also developed for projects, researchers, and companies (see section (6.3.4, tables 11, 12, figures: 100,101,111, 112, 113, 114, 115, 116, 117, 118, 119, and 120).

The concept of the cartography of innovative communities, their contributions and disagreements was enthusiastically received by both the observatory network and the co-innovation members. The pilot developed and described in the case study proved the usefulness of such approaches. The co-innovation members felt that in order for the cartography activities to be sustainable and scalable a formal commitment should be made by policy makers in connection with their strategic programmes and funds. They have voiced this concern to policy makers of the TEL and Education and Culture units See workshop 5: section 6.5.5 and section 6.5.6 in the case study. The co-innovation members felt that it would add significant support for the successful realisation of the Dynamic part of the co-innovation roadmaps (operational activities).

Mapping activities in the case study: 'Capturing the voices of TEL communities'

As analysed in Chapter 3, a systems approach, involves modelling the views, action designs and assumptions of social systems. Models are employed as research tools to describe or explain a system or as tools to assist strategic planning based on foreseen events and suggest actions in short, mid and long terms (Flood 2010). This involved coding and abstraction (modeling) of information and results by the co-innovation group participants and by the observatory network. The co-innovations participants had the opportunity to use conceptual modelling during online and offline sessions, in order to model, synthesise, compare, contrast and extend the initial results produced during the workshops. In addition, the observatory network used conceptual modeling in order to map and abstract the results from the various Observatory activities and inform the roadmaps of the co-innovation group. Conceptual models proved to be a good way to compare, and extend the maps and/or the roadmaps developed by different groups using different approaches, starting points, interests, goals and motives and therefore to increase their chances for a mutual understanding of different perspectives. Towards these goals, conceptual modeling tools (e.g. CmapTools, Conzilla, mind maps), web-based tools (such as Google documents, skype), social networking tools (such as Facebook, LinkedIn, tweeter, RSS feeds) and a web portal were employed in order to support disagreement management and build connections among groups and individuals based on shared concepts that link a multitude of different perspectives (e.g., commenting, linking and refining each other's concepts and/or inter-concept relations).

During the case study, the cartography mapping was mainly performed by the observatory network. Gate Keepers were responsible for entering and maintaining the information at the portal spaces and liaison with the co-innovation members (see observatory structure section 4.2.5). In order to capture the voices of TEL communities, the different events and trade fairs that TEL stakeholders and industry players usually attended were identified, as well as the online collaboration platforms, and other social networking web-spaces that they used. The principle under this approach is to meet these stakeholders and experts in their own communities and networks, join their events and establish a presence to their social networking sites and online collaboration spaces. Roadmapping events were often co-located with other important industry events and scientific conferences, along with other activities such as interviews and surveys, in order to understand both, the state of play in TEL and the future directions of TEL stakeholders. In parallel, other TEL roadmaps were collected and analysed as well as the majority of the research and development EU projects. In this way, the 'co-innovation' group has been set up and later complemented with additional stakeholders who shared common or complementary interests, activities and assumptions about their future visions. When major conflicts are identified, different clusters of 'co-innovation' groups would emerge. In the specific case study, there was no need for splitting groups. The 'co-innovation' roadmapping group was created in order to cluster and manage all these activity systems. The initially invited organizations and networks in this 'co-innovation' network had to already be working on some aspects of schools education and they where identified from the initial cartography. They were also asked to share their activities, motives, visions, current projects and histories with each other using a shared google document (see sections 4.3.2 & 6.5.1, and figures 71&72). Open source tools which the innovative communities already used or they were familiar with synthesize the co-innovation's group shared infrastructure. Therefore, the different communities in the 'co-innovation' network were able to meet, exchange ideas and work together in shared online spaces. The forward looking activity of the TEL-innovative communities was mapped using various modelling techniques, in order to map the existing state of the art State-of-the-Art and stay of play in TEL research, industry and practice in Europe and elsewhere. Appropriate conceptual tools (e.g. Conzilla; mash-ups; concept maps; social networks) were used in order to represent important characteristics emerging from the State-of-the-Art review. Combining the Mapping activities of the observatory network with Roadmapping activities helped the formation of a co-innovation group based on shared insights and common directions as well as it enabled a better understanding and better sharing and exchange of knowledge within and between TEL communities. The Roadmapping activity had built capability across TEL communities in creating a sustainable dynamic roadmapping process suitable for TEL (which includes a foresight process and goal-oriented planning). These activities were supported by strategic analysis of weak and strong signals of future TEL trends via an roadmapping alert system (Observatory). This enabled a two way feedback between co-innovation group and the observatory. The co-innovation participants via the roadmapping process (consists of 5 workshops and several online collaborations) were successfully sharing their objectives, goals, achievements and roadmaps and they were indicating to the observatory areas to look for signals, trends, technologies, resourcers, etc. Through the observatory, the co-innovation group was connected to other TEL stakeholders, experts and communities (e.g., active European TEL research projects and initiatives, educators, technology providers, etc.) in order to better understand what is going on within other TEL stakeholder communities; share and exchanging knowledge on future perspectives; and better understand emerging trends and developments in TEL of which the co-innovation participants might not be aware yet or tend to overlook because they were considered undesirable. As mentioned above, these activities were supported by a continuous horizon scanning observatory function that reported relevant findings to the innovation clusters, allowing them to adjust and if needed radically change their roadmaps, context scenarios or their desired futures if challenges mean this is no longer feasible, or further develop it if new opportunities arise.

PhD students were involved via the JTEL summer schools and EATEL journal in mapping the research topics in TEL. PhD candidates have created structured information about their research (such as sub-area of TEL, methods, artefacts, technologies, etc.,) and the projects that they were participating in. More than 40 PhD candidates have contributed to a series of special issues that focused on mapping the state of the art in particular subareas of TEL. A survey was first conducted using face to face workshops with the students by a team of 2 people headed by the researcher in order to identify the research elements in students' work and the related research areas in TEL. Based on this first survey, the observatory network created the initial metada for TEL stakeholders electronic portfolios. The PhD students, TEL companies and TEL researchers were able to edit and add their entries electronically, creating semantic portfolios for their research and practice. Engaging the PhD students was not an easy task. Good motivation for their participation proved to be the matching of their research interests with potential work opportunities in research projects of the current TEL community and the interaction and ideas exchanging with well-known TEL experts during the JTEL summer schools (see section 6.3.4, and table 12). Their contributions to a series of special issues in IJTEL (International Journal of Technology Enhanced Learning) journal focused on mapping the state of the art in TEL was an additional motivating factor to participate in the mapping activities. The students have submitted 40 papers. The Observatory network employed also two modellers (one was the researcher and the other a very experienced senior modeller). They were responsible for modelling the results of an extended survey with the TEL projects which was the basis for the structure of the research projects profiles metadata for the confolio. Metadata applications profiles to describe projects and research have been developed (see table 12, section 6.3.4).

7.2.3 Extension of roadmapping approached via integration of change management

As analysed in the sections 7.2.1 and 7.2.2 above, a series of questions arise in case of systemic innovations: Who are the stakeholders, who should be brought together, who can change or influence the system? How can we identify tensions and conflicting areas among them? What is the role of the R&D community? What are the routes to adoption of the roadmapping recommendations? What are the interests, concerns and directions of the important groups who can influence the future? This implies that a single desired future should not be presupposed for complex domains, but several futures, some of which, may be informed by shared strategic perspectives that will be negotiated at national, regional levels and local levels. In addition, the cartography which was discussed above brings up and models the assumptions of different players in the domain and provides an understanding of each other's motives, solutions and approaches therefore help to manage and bridge disagreements. Dynamic roadmapping adopted the Adner's approach of 'value blueprints' for innovation management (see sections 2.2.7 & 2.5.4), in order to map and align such aspects and the respective actors related to implementation of the co-innovation roadmaps (see section 6.5.5, *workshops: 5: Stress-testing initial roadmaps*). An important difference between Adner's approach and the 'Dynamic Roadmapping' is that Adner, similarly to Moore's model, appears to be primarily focused on the supply side, with the final end user or customer placed at the end of the chain, but not involved in the co-innovation process. This is an oversimplified model based on linear supply chain thinking. In reality, it is the interplay with users and other intermediaries that play an important role in the development and evolvement of innovations (Carlsen et al. 2010), (Tuomi 2004), (Tuomi 2002). In case of TEL a user-centred innovation model is more relevant (Rogers 2003). For example, consider the LMS (learning management systems), which were first developed as tools for assisting with administrative functions related to online courses such as enrolment, grades, announcement of classes etc. Teachers have used these early systems and they have assisted in their improvement and further development towards personal learning environments (PLE), via their integration with learning and assessment repositories, learning designs, talent development, personal portfolios etc. Therefore, the technological innovations are re-invented in a social context (e.g. learning and teaching in various social contexts) and in turn contribute to shaping society, for example providing new possibilities for education (e.g. via MOOCs), or increase chances for better employment (via personal competency portfolios).

In addition, ‘end users’ in systemic innovations are considered as more complex, with multiple decision makers involved (e.g. in TEL this may involve ministries and departments of education, agencies, heads of schools, teachers, parents and learners), each of whom have a key role to play in the co-innovation. The whole functional and innovations chains of supply/product/service/delivery may have to change, and an agreement of various actors might needed in order to implement the new innovations. Again, in TEL, these may include suppliers, producers, distributors, value-added resellers, content developers and providers, curriculum and examination boards, who may be considered as intermediaries, and education authority decision makers at national, regional and local levels, as well as educators and learners who can be considered an extended set of End Users/Customers.

(Adner 2012) address issues of multiplayer innovation networks, but he does not include roadmapping or foresight techniques, instead focusing on the important question of ensuring that all the players on the value network can see positive benefits to themselves. While the ‘Dynamic Roadmap’ approach had seen the importance of gaining agreement on goals, the Adner’s approach was integrated in order to strengthen this aspect in more concrete, financial terms. In this sense, ‘Dynamic Roadmapping’ is based on an inter-organisational approach, where stakeholders (and their networks) first establish agreements about their future and then coordinate their actions. They are producing their own roadmaps for them to follow.

7.3 Development of an Observatory for innovation in TEL: A practical implementation of integration of micro and macro contexts

One of the fundamental ideas behind the ‘Dynamic Roadmapping’ is the development of a conceptual-Model, which will provide a framework for the needed synergies between different types of innovations and their respective roadmaps developed in a dynamic way by different innovative communities. In this way, Roadmapping is used as methodology to harness established communities and increase the chances of a sustained synergetic relationship between them. As demonstrated by the case study (sections 6.5.6), TEL innovative communities are diverse in both their activities and their understanding of the main issues in TEL. For example, a researcher has different goals and planning from a TEL vendor or a TEL adopter such as a learning institution (e.g. school) or their learners. Each one of these types of stakeholders will be creating their own individual plans and roadmaps according to their specific needs for innovation management, research and long term planning, but each of them alone cannot bring them to effective implementation, thus they need to co-innovate together and coordinate their actions for implementing their innovations.

7.3.1 Separating Intelligence gathering and analysis from Roadmapping process

In ‘Dynamic Roadmapping’ the actual roadmapping process, which is closer to a strategic planning and innovation management process is separated from the process of collecting information with regards to market, user requirements, PESTLE and industry drivers, state of the art and profiling of trends, which are considered to be intelligence information. In that way, the outputs of such activities can be used, when and where required in the roadmapping process (the intelligence part of how information are used as “food” for the roadmapping process) and provide evidence to back up the strategic decisions of the co-innovation roadmapping groups (e.g. evidence to support and monitor the published roadmaps). Another reason for this separation is that the roadmapping process itself relies on tacit knowledge (people working together making strategic plans and synthesizing information), therefore it is a learning process which is difficult to externalize or transfer and to effectively integrate external contributions. Information collected on technologies and drivers is more easily expressed as explicit knowledge which can be codified, grouped, documented and evidenced. Consequently, having such a system in place provides us with a platform to solicit, record, document and classify information coming from external sources and people outside the co-innovation roadmapping groups. This information is also becoming part of the cartography, which provides a continuous picture of the domain and the main changes over-time. This separation is evidenced in the co-innovation ‘Learning Frontiers portal’, which was designed in two spaces: The Emerging Futures Observatory (intelligence gathering part) and the Creating Futures Roadmaps (roadmapping part) (see section 6.3.1 & Figures 83, 84, 85).

Following the above principle, roadmapping is the process of deciding on “know why”, “know what” and “know how”, while TEL intelligence can provide us with the information of “what we should know” or be “aware of”, when we try to answer these questions (what we should know about “where are we now”, “how things historically progressed”, “where things are heading”, “where are the conflicting approaches”, “ where the capacities are forming”, “who are the movers and shakers in the industry”, “who are the disruptors”, etc.). Therefore, the co-innovation roadmaps capture ideas/views/analysis on what to do and why and how. The intelligence gathering and analysis is a parallel process which provides the co-innovation group an increasing understanding to inform such actions (why, what, how) and a monitoring function, which provides alerts when this information is changing. In this perspective, the starting point was to identify information resources organised into information product types such as driver, weak signal, vision/desired scenario, roadmaps, context scenarios, technology trends, new pedagogies, type of TEL actor, etc. as information products. These then, were made accessible to the public in the most usable and reusable way in order to be annotated, assessed and communicated to the co-innovation Roadmapping groups. *Scan, Mine and analysis (sense making)* functions were also identified.These functions were more connected to the process than the information products. Figure 169, depicts this relationship between the observatory function and the co-innovation group. Main functions include topic and text mining, weak signals identification and analysis, Delphi, technology review, and SNA. A more detailed analysis of how the observatory was developed in the case study and the main functions is provided in the case study sections 6.3 & 6.4).

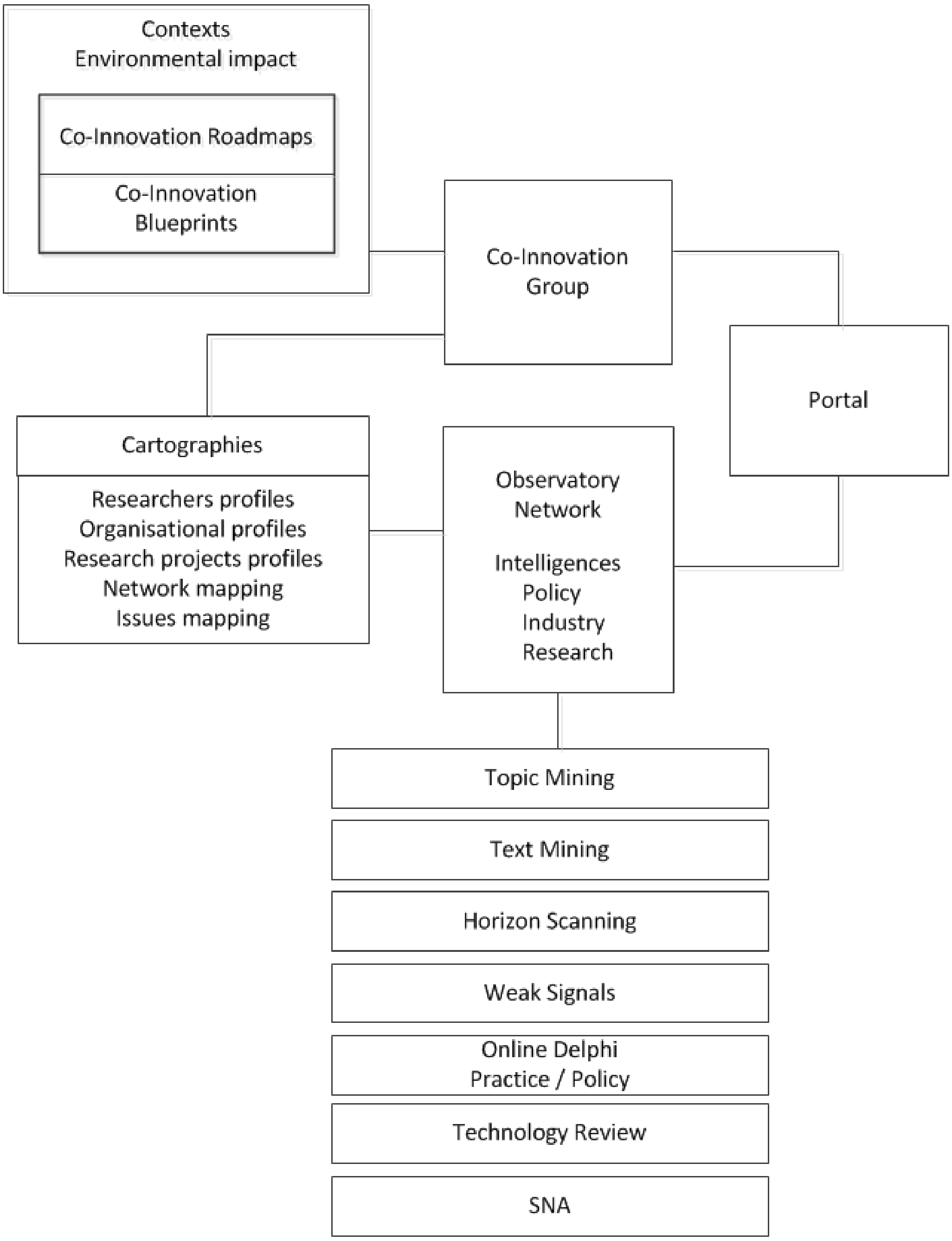

Figure 169;

Therefore, Dynamic Roadmapping provides and integration of Policy, Research, Industry and Practice roadmaps (see sections Chapter 3: Challenge C; section 6.4 & 7.3)

Figure 170 depicts the new synergetic relationships between co-innovation roadmapping and other types of roadmapping communities (notably *Research, Policy Foresight and Industry*). This integrating activity is driven by the two activities of *Co-innovation Roadmapping* and Innovation *Observatory*. The *Co-innovation group* is formed from all necessary co-innovators, adopters, decision makers and users, which make up the co-innovation ecosystem of the particular domain setting or segment. The TEL Observatory provides information to co-innovation group as different intelligence streams, in terms of both, Macro factors of change *(Policy foresight), research (innovations, discoveries), cartography of the TEL domain* (people and networks, capacities building, topics, tensions, visions, roadmaps, new learning paradigms, etc.) and *state of play (industry)*. It connects the different roadmapping communities via shared activities, and via the integration of their results and roadmaps. In reality, it is a two way stream of information exchange. The co-innovation group also provides to the observatory areas and topics to watch that relate to aspects of their desired futures, roadmaps and the uncertainties in their context scenarios.

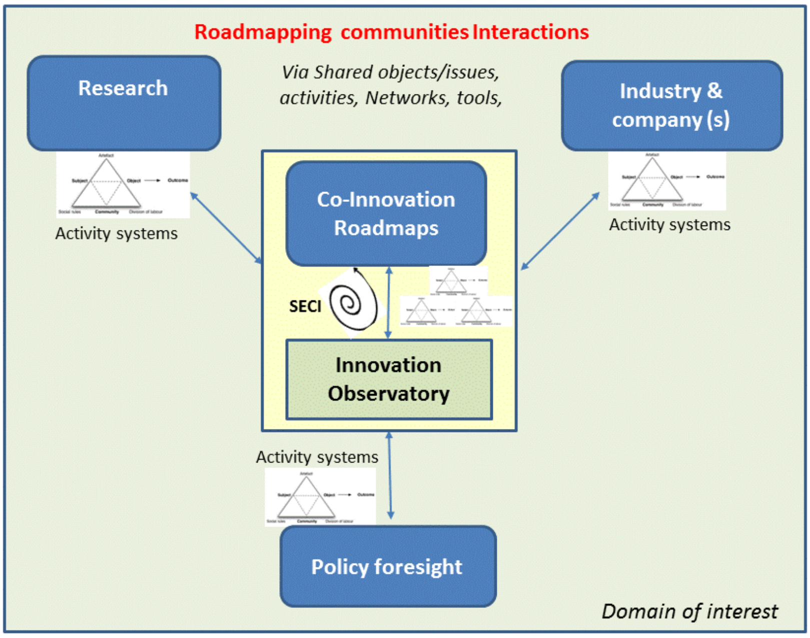

Figure 170. Synergetic Relationships between Co-Innovation, Research, Industry and Policy Roadmaps

The two-way relationships between the Co-Innovation and the other three types of roadmapping are as follows:

Co-innovation ←→ Research

← A Research Roadmap provides input to a Co-innovation roadmapping group, indicating what research outputs can be expected during the course of their roadmaps implementation process (input to workshop 4, and 5).

→ Novel requirements and context scenario uncertainties, arising from a co-innovation group's work, can be used to raise new research questions, as well as to provide a new context for research and generate new research data (workshops 4 and 5).

Co-innovation ←→ Industry Sector Roadmapping

← An industry sector roadmap can feed into the forward planning of Co-innovation roadmaps. *Industry roadmapping* activities assess the market relevance of the co-innovation group visions and identify the opportunities for innovative products and services in the form of specific value propositions (workshop 3), which are fed back to the co-innovation group (workshops 4 and 5). They also capture opportunities on application areas stemming from the exploratory scenarios of the research groups (workshops 1 and 2).

→ A Co-innovation roadmap can inform the industry of new emerging requirements and new innovation opportunities (workshop 3).

Co-innovation ←→ Policy Roadmapping

← A policy roadmap is able not only to inform existing Co-innovation roadmapping groups on foresight issues (workshops 1,2,4,5), but also to encourage the creation of new co-innovation groups.

→ A Co-innovation roadmap can also inform policy of new emerging challenges and areas that may need additional policy support (workshops 4 and 5).

(For further analysis of how Policy, Research, and Industry where integrated please also refer to sections: 6.4 in the case study).

Figure 171 depicts this integration at the sector level innovation communities via the co-innovation group.

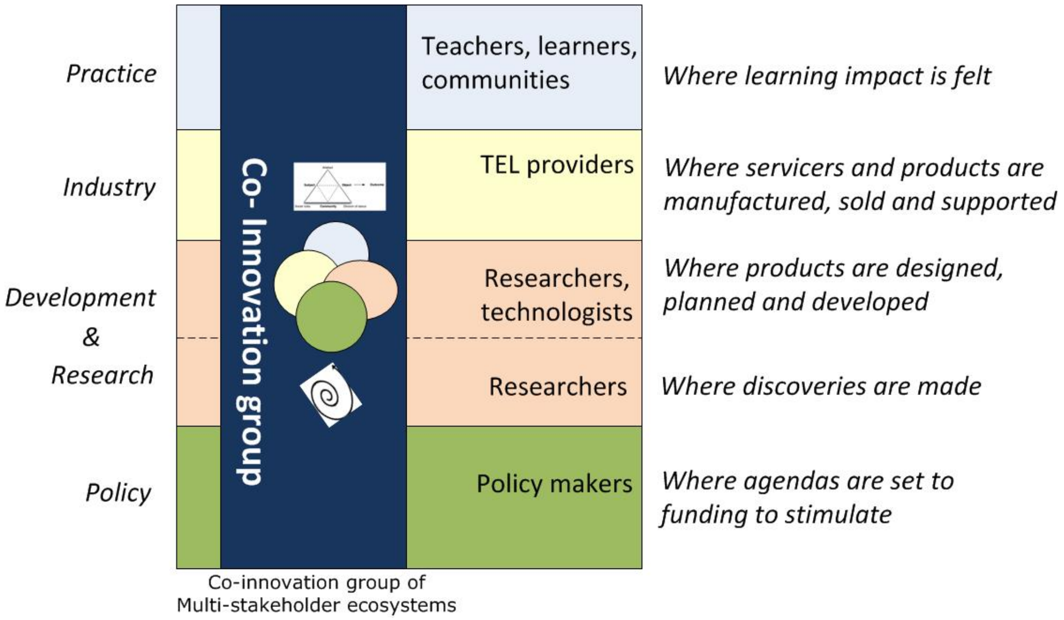

Figure 171: Integration at the level of sector-stakeholders innovation communities: amplifying their efforts via SECI and interconnecting them via their shared objects of their activity systems.

Stakeholders from research, industry and practice could describe and modeling their own projects on the Observatory platform using dedicated profile portfolios at Confolio tool, which was integrated and presented at Conzilla and at the shared portal. The idea behind these profiles was to enable stakeholders to identify and match other interested parties for collaboration and enhance the co-innovation group membership. The Observatory shared portal included a Delphi study in a Dropbox environment, a dashboard for collecting intelligence on relevant projects, a twitter timeline, 'Signs of change' human curation and search, a PESL classification section and other innovative practices; and an extensive overview of the state of the art in learning technologies in the research, academic and corporate worlds (see sections 6.3 & 6.4 in case study and tables 11 & 12). When possible, the observatory network used annotations, which were added directly at the roadmaps context maps, using CmapTools and presenting the at Conzilla browser. These were forms of alerts for the co-innovation group to re-assess aspects in their roadmaps. Such approach was found very helpful from the co-innovation members (see workshop 6.5.5 and figure 159).

The Observatory proved to be great means to build a **shareable prototype of the foresight capability** that individual innovative TEL communities or groups of collaborating communities used in order to:

- identify the emerging visions and concerns of their stakeholders in relation to LET and TEL;
- develop scenarios for change that affects their stakeholders and identify the factors of change, with an analysis of the opportunities and threats they present
- Collect data that may be/prove to be of value to TEL communities (candidate forms of such data include surveys (Weak signal, DELPHI) and polls involving representatives of stakeholders in the validation of factors of change and in the elaboration of future scenarios of evolution)
- Review, comparison and synthesis of existing RTD on change factors affecting TEL (e.g. within TEL projects such as PROLEARN, ICOPER, STELLAR, ROLE, TARGET, CETIS projects, ELIG, FUTUREWORK, etc.)
- Strong signal and Weak signal Analysis and options for the evolution of each of the change domains identified

As depicted in session 6.4 the Observatory used data sources such as:

Online Questionnaire and Interviews: more than 50 TEL providers have been interviewed at Learning Technologies, LearnTec, ITK2012 (Interactive Technology in Education) at E-Learn Expò. They participated together with other industry contacts to an online survey on learning technology trends. Analysts' reports: predictions on future learning technologies from Ambient Insight, Gartner, Cisco, Cegos, Ovum, and Doloitte have been considered. Public TEL studies: reports from Horizon, Stellar, GROE and Towards Maturity have been analysed. Scientific publications: an automatic data mining on more than 2500 TEL conferences proceedings (from ICALT, ECTEL, CAL, ICHL and ICWL) and blogs was conducted to show the frequency of the terms of trends (e.g. "cloud") and the average "subjectivity" of abstracts containing the terms; in addition, the same sources of data have been used to generate graphs which summarise the words preceding and following a chosen word (or group of words e.g. "learning object" is possible). These graphs provide a supplementary aid to interpretation of what the trends are in FP7 TEL projects: 22 TEL projects have been deeply analysed in order to extract the projects' technologies, their maturity level and drivers. The work has seen the involvement the projects coordinators and the study of project web sites and online project documents.

Services provided by the co-innovation group

- Analysis of trends of learning technologies.
- Analysis of 22 FP7 TEL projects
- Analysis of the interviews and questionnaires of the TEL providers
- Sata mining of TEL conferences proceedings and blogs (see http://arc12.github.com/Text-Mining-Weak-Signals-Output/History%20Visualiser/Union%20C%202006%20to%202012/Groups.html and
- http://arc12.github.com/Text-Mining-Weak-Signals-Output/History%20Visualiser/TEL%20Blogs%20700%2020090101-20120912/Groups.html
- Maintaing a list of major trends in learning technologies and their respective timing
- A description of the emerging technologies and the analysis of trends from different perspectives (projects, analysts…) for the Learning Frontiers portal (see for instance http://www.learningfrontiers.eu/?q=content/cloud-computing)
- Co-organisation of the TEL industry experts workshop at EC-TEL2012
- Crowd sourcing
- Collection and analysis of further TEL sources (blogs, publications, projects – online data stream) – further Mediabase developments
- Provision of dashboard-like open access to media-base queries (example queries, explanations)
- Clustering of information according to PESTLE (Tagging, Dictionary)
- Generation of mini-scenarios out of ongoing signal analysis
- Delphi-review of importance and implications of signals (clustered by scenarios
- Production of several periodic reports to the co-innovation group.

Special periodic reports included:

- Reports on Socio-economic developments most relevant to emerging new learning paradigms. Reports from the Delphi studies. These reports assisted the co-innovation group to update their goals and visions derived from *workshop 1: shared perspectives* and *4: initial roadmaps.*
- Technology review and Gap Analysis reports: collected data of stakeholders (TEL adopters and providers) views regarding strengths, weaknesses, opportunities and threats that could affect TEL for the next 10 years. Involved communities included ELIG, IMC and eXact customers and additional identified experts. The Reported results supported the co-innovation group's roadmapping activities (*workshops 3: industry perspectives, 4: initial roadmaps, 5: Stress-testing initial roadmaps)* and the updating of the initial roadmaps during online meetings). Annotations were provided directly at the Roadmaps Contexts maps. Gap Analysis Report, Reports the analysis of strengths, weaknesses, opportunities and threats of the most relevant identified TEL contexts (learning processes, organisations, technologies) and a gap analysis in terms of functionalities, modes and processes of TEL between those of today and those required for the identified co-

innovation's futures visions.

- Market relevance reports that assisted the co-innovation to assess the TEL market.
- Report results from interviews and workshops to support of the co-innovation's roadmapping activities.
- Survey results from EC FP7 TEL projects on TEL research, technologies and trends. The results will be modelled with Conzilla.
- Reports on specific recommendations grouped accordingly to the short, mid and long term roadmaps of the co-innovation group, filling the gaps between today's and tomorrow's capabilities. These reports included market potential assessment about the time of adoption of technologies described in the co-innovation roadmaps in the core markets of TEL. They also aimed to assist the co-innovation group to create and update its innovation value blue-prints for adoption (see section 6.5.5 *workshop 5: Stress-testing initial roadmaps* and online discussions afterwards).

A detailed analysis and examples are provided in the case study section 6.3 & 6.4. See also summaries in tables 11 and 12.

7.4 Dynamic Roadmaps development via a co-innovation group: lessons learned and challenges

The case study in this thesis demonstrates how a 'Meso-Level' group of stakeholders was successfully brought together in order to apply the 'Dynamic Roadmapping Framework' and develop their roadmaps for schools' education. 134 members from 19 European countries formed the co-innovation group. In addition, a facilitation team of 3 people headed by the researcher was established at the very beginning of the roadmapping process. This team supported the innovative stakeholders' communities with tools and web-documents in order to form the co-innovation group and apply the 'Dynamic Roadmapping' process. Seven people were involved as gate keepers responsible for the Observatory function (see sections 4.2.5, Figure 73). The co-innovation group worked together during **5 workshops,** and during several follow-up online meetings among its members, the facilitation team, and the observatory network in order to develop and start the implementation of their roadmaps. These workshops were key milestones in successfully implementing the Dynamic Roadmapping process.

The lessons learned and the particular challenges related to this work are presented below:

7.4.1 Risks in advocating a single future scenario

One of the key milestones for Dynamic Roadmapping is uniting a group of stakeholders who are forming the co-innovation group in agreeing on a common purpose, or desired future. *Workshop 1: Shared perspectives*, uses a modified Future Search Conference (FSC) methodology to bring the Co-Innovation group together in order to create their shared futures in the form of desired scenarios and identify and rank forces from the environment that could impact those futures (see section 6.5.1).

There were some significant challenges related to the integration of FSC in Dynamic roadmapping process. FSC has generally been used to resolve one particular "stuck issue", which those involved, once agreed on their desired future, can then move forward and solve the problem in the short term (Ramírez et al. 2010). Therefore, it advocates a single future, which is desirable by all involved stakeholders, and it typically addresses a single problem to be solved. In Dynamic Roadmapping approach, due to the greater uncertainty, the longer planning horizons, and the systemic nature of the targeted innovations, we cannot assume that one future or one straight line scenario will be materialised but instead, several plausible futures can emerge. FSC approach risked to miss the exploration of multiple plausible futures which are based on different assumptions that stem from the divergent thinking that is going on within the TEL area - and which in some cases goes on "beneath the radar screens" of the dominant players in the field. For example, innovative solutions are often coming from technologies around TEL domain, or advocate new ways pedagogies. In addition, multiple futures approach provides space for surfacing tacit assumptions, which can then be discussed and understood.

It is important to stress that the co-innovation group did not agree on a single fixed and over detailed future for Schools in Europe. They agreed on a common visionary framework (described in short vision stories, classified in common themes and later modelled in conceptual maps (*see section 6.5.1, workshop 1: shared perspectives and follow up activities*). Such approach would allow the co-innovation group to seize future opportunities, which might not be evident today and to be able to deal with future surprises. According to the 'Dynamic Roadmapping' methodology, it was important to create a soft infrastructure (co-innovation network building capacities for innovation) and a design (roadmap) in order to support open and seamless learning school environments in a variety of situations. The aim of such common visionary framework was to support openness and different ways of implementation, empowering stakeholders to take responsibility through their contributions. Moreover, this shared vision would be contextualised in the stakeholders own cultural, political, legal, economical and operating environments. Therefore, a synergy between the different types of stakeholder communities (such as research & development, sectors-stakeholders, industry players and policy making, etc.) is essential to provide common directions based on clear future visions and the capacities for implementation. It is clear that the vision will change and need to be agile. The aim was on creating a contextual vision within the stakeholders groups. Provide a methodology, past and current information, and an infrastructure for the stakeholders to meet and collaborate in order to create their visions within their local contexts and segments. The global shared vision provides the common perspectives for different stakeholders groups in Europe without a struggle for perfection, and is negotiated to middle point as a reference vision, with emphasis on contextualization and involvement of different groups in the transformation process in a given context. Context scenarios have been used to stress-test the framework and adapt it.

Another important difference between the FSC and the Dynamic Roadmapping approach was that the desired futures in Dynamic Roadmapping, in contrast to the FSC approach, were developed prior to the exploration of the change factors (trends, signals, tensions) that could impact schools' sector *(see section 6.5.1, workshop 1: shared perspectives)*. This was done in order to avoid the problem of looking at the future as a projection of today's trends and possibilities. Therefore, the future is not restricted to our current assumptions, limitations, and capabilities. It has an evolving and transforming element and not progressing.

A context scenarios based approach was also used *(see section 6.5.2, workshop 2: Context Scenarios)* in order to a) pay attention to changes in the operating and contextual environments, which could affect the desired future and the stakeholders' roadmaps, b) stress-test the roadmaps and scenarios and adapt them. This approach helped to visualise several possible futures were the desired future could be played out and minimised the FSC challenge. *A monitoring function* was also developed by the observatory in order to alert the stakeholders of changes that can influence their desired futures and roadmaps.

7.4.2 Risk of utopias futures with no chance for implementation

FSC is a **consensus building approach**, which advocates that all stakeholders will agree on the desired future (Ramírez et al. 2010). Therefore, the focus is on common ground, while disagreements or conflicts are not addressed. As analysed in sections 3.1.2, 4.1.2 striving for a common ground can backfired since a) only strong voices will be taken into consideration, and b) participants will agree on over glossy utopias without strong commitment towards their realisation. In Dynamic Roadmapping, overall risks are managed and minimised by integrating top-down and bottom-up approaches. The ongoing Cartography activities (see previous analysis in section 7.3 and in Case study sections 6.3.2, 6.3.4, 6.4) combined with the ARE-IN principles from Future search enabled the co-innovation group to reach a capacity of wide range of representative stakeholders. A cartography function in the very start of the process provided a good understanding of the systemic relationships involved, including any tensions, issues and other factors that can influence the collaboration of the co-innovation group. The profiles of research projects, researchers and commercial organisations together with the state of play interviews provided a good opportunity for deeper understanding the key issues in TEL and what were the agendas, future plans and research approaches of the TEL players. Combined with the Social Networking and topic mining analysis, a further understanding was provided in where the power structures were developing in the field, in terms of who is collaborating in what research projects with whom, who is publishing with whom, what are the influential topics and TEL approaches. This understanding provided good collaboration opportunities for likeminded individuals to be brought together who have similar or complementary visions, goals and problems.

The **ARE-IN checklist** (see section 6.2) were used as a top down tool for setting up a viable group drawn from disparate stakeholders and ensuring that all necessary roles of stakeholders and diversity of voices were included in the co-innovation group. Identifying players in these categories with a shared interest in the area of focus via the cartography provided an initial working list of who is needed to be involved in a co-innovation roadmap. The co-innovation members brought their varied and complementary skills, incentives and resources. It is unlikely that a complete Co-innovation group, with all the required key stakeholders, will be formed at the outset. For example, in the case study, we found commercial developers, while interested, were reluctant to engage more fully, until some concrete proposals were formulated and they could see potential demand. This was in part the result of increased pressures on them created by the recession and lack of resources. After the initial participants felt that they had sufficient committed members, they started on the initial planning stage. However, they were made fully aware by the facilitation team that other key stakeholders will all have to be won over and engaged if the innovation venture is to be ultimately successful. The on-going cartography and information of the emerging innovative communities' clusters were used in order to make informed decisions on how to expand the initial co-innovation groups (see sections 6.3.2, 6.3.4, 6.4 in case studies).

7.4.3 Getting the commitment of the stakeholders to participate in the FSC

Another difficulty rose from the nature of the FSC. FCS sets out the detailed processes for a typical 3 to 5 days Search Conference event (also see section 2.1.7). This model drew upon a well-established and widely used method for gaining the commitment of decision-makers from across an ecosystem. It assumes that representatives of all the main types of stakeholders involved in the system in focus, typically around 64 people, agree to attend a three-day meeting to develop a shared future, and to formulate and commit to the actions they see as necessary to achieve it.

Such approach required a too-high level of commitment and resources from participating members of the TEL communities, in this case (practitioners, users, policy makers, industry, researchers). During turbulent times, it becomes more and more difficult to get the right participants, including those who have authority to act into one room for more than a day, let alone a whole week or three days. Such constrains reflect the more hostile nature of the external environment, which is introducing more turbulence and pressure on the wider TEL community. Stakeholders' time was already booked with work, travelling, many meetings, training activities and they really valued the personal resources left for themselves. In addition, it proved very difficult to recruit sufficient numbers of participants, who had decision-making authority and who represented the major TEL communities of interest for the co-innovation group, to create a viable FS event. Thus, partly because the external environment for TEL had become much more volatile and partly because of the bad economic climate, it had become harder for many TEL stakeholders to find resources to attend such a weeklong meeting, something which turned out to be a big problem for them. To cope with this risk, the FSC was planned as a one-day meeting, which was co-located after another broader one day consultation meeting with TEL experts on visions and problem related to TEL field. The co-innovation participants were invited to attend both meetings in order to start with a broader horizon problems and topics in TEL, and then the next day, during the FSC, to focus on the School's sector. The participation to the first day event was not obligatory, but it was a good chance for start building trust and collaboration via socialisation with the stakeholders who had the time to attend it. In addition, to solve logistical problems, typically, the co-innovation meetings were scheduled to coincide with regular events such as industry trade events and scientific conferences that had traditionally attracted good numbers of the kinds of TEL users we are targeting; In order to overcome the problems stemming from compressing the FSC in a one day event, a hybrid approach was taken that uses adapted Future Search methodologies in both virtual and face to face environments. The FSC was significantly extended by follow up online activity before and after the meeting. Therefore, participants could choose to participate in face to face or online collaboration activities or both. The same logic was followed with all the other 4 workshops. They were limited to one day to a day and a half events, co-located with other important events in the field and extended by facilitated online and offline collaborations.

7.4.4 Collaboration with Industry

Collaboration with industry was proved to be even more problematic. Although, the industry stakeholders should ideally be participants of the co-innovation group, in practice, it proved difficult to engage a larger number of them during times of financial uncertainty. Companies' in the field founded it much harder than 1-2 years ago to allocate sufficient resources to permit their senior staff to spend several days away. They also viewed the area as mature in terms of traditional e-learning systems, and the schools domain in particular very difficult to change, therefore not so promising for transformative and radical systemic innovations. For this reason, a three steps approach was followed to engage participants from the industry:

1. The roadmapping facilitation team tried to first approach the industry stakeholders in their own events and trade fairs and co-locate meetings and interviews (see sections 6.4.2, 7.3.1, and table 12).
2. During these interviews, the industry stakeholders were informed about the co-innovation group and were invited to a dedicated workshop which was organised within the EC-TEL conference (see section 6.5.3, *workshop 3: Industry perspectives*). This workshop was co-located with this major TEL conference related to the area of the roadmap, where industry participation was expected to be high.
3. At the end of the workshop, the industry participants were invited to join the co-innovation group.

Therefore, this workshop operated as a bridge between the industry players and the co-innovation group. Another important motivation factor for involving the industry was the need to assess the co-innovation's visions in terms of their attractiveness to today's vendors, provide an understanding of what were the value propositions from the industry, and how relevant the visions were to industry's future plans. The industry players who felt that they could align their plans with the visions of the co-innovation group had a great incentive to join them.

7.4.5 Dynamic Roadmapping as a systemic approach for bridging foresight with roadmapping and change management approaches

Dynamic Roadmapping integrates Foresight, Roadmapping and Change management approaches in order to plan, develop and manage systemic innovations (see also section 3.1.5 and figures 62, 63). Dynamic Roadmapping views Roadmaps as a system which consists several internal systems (e.g. visions, value propositions, roadmap design, actions, and resources). As analysed before (see section 7.1), since the system (i.e. desired scenarios, initial roadmaps) is very complex and uncertain during the design process, an over-specification of the system would be waste of resources. It would restrict the system's agility and possibility to be dynamically adjusted, based on the system's increasing knowledge of its contextual and transactional environments. Consequently, as the dynamic (operational) part of the system progresses, the visions in the desired scenarios will evolve as the stakeholders' own actions will reveal different opportunities, which have not been obvious at the design stage.

As analysed in Chapter 3: Section 3.1.3, the success of the dynamic part of the roadmap depends upon the calibration of the lawful intra relationships - within the system and inter relationships - between the system and its environments. According to this analysis, a system is understood in terms of its lawful relationships (Ramirez et al., 2010, p.24). The description, analysis and mapping of these relationships (i.e. between the forces and actors in the system; among the system and its environment; and the environment and the system) is of paramount importance in dynamic roadmapping.

In practice, the only element that the co-innovation group could control, or modify is the transactional environment of its stakeholders, who are forming the co-innovation group. This is because the stakeholders and their actions are part of this environment. The transactional environment is defined as the sum of the transactional environments of each stakeholder in the co-innovation group. By calibrating their goals, and their actions the stakeholders can evolve the commonly created roadmap. In reality, by changing their transactional environment through their own acting, the stakeholders are able to influence both the development and evolution of their roadmaps and their influence on their contextual environments. Therefore, similar to activity theory, the roadmap artefacts are runaway objects which are redefined and evolve according to the renewed interests and objectives of the stakeholders and from new opportunities stemming from the ongoing collaboration activities of the co-innovation group. Since the interplay of stakeholders actions are also driven by the roadmap, both the roadmap and the co-innovation activities are mutually influencing each other and co-evolve in a learning process. Changes in the objectives and interests of the stakeholders are also depended on factors from their external contextual environment and the stakeholder's attitude towards these external factors. Therefore, the three environments (co-innovation, transactional, and contextual) are interrelated and evolve together. This is defined as the agile, dynamic quality of the roadmap.

A series of questions arise. Who are the stakeholders, who should be brought together, who can change or influence the system? How can we identify tensions and conflicting areas among them? What is the role of the R&D community? What are the routes to adoption of the roadmapping recommendations? What are the interests, concerns and directions of the important groups who can influence the future? As analysed above, this implies that a single desired future should not be presupposed for complex domains, but several futures, some of which, may be informed by shared strategic perspectives that will be negotiated at national and regional levels, while others emerge from a local level or, as suggested, from *value networks of inter-dependent co-innovators (co-innovation groups).* In order for systemic innovations to be successful, the “functional logic” of the entire innovation chain and its sub-chains (e.g. suppliers, manufactures, distributors, value-added resellers, intermediaries and consumers) should be taken into account, as well as the strategic coordination of the required changes. Hence, the dynamic roadmapping approach supports the creation of multipurpose and sustainable network ecologies, practices and processes and thereby builds diverse communities of technology innovators, users, and key stakeholders. Moreover, innovations in any part of the ecology could trigger changes in the entire innovation chain and its sub-chains. Therefore, it is important to understand how the developed technology integrates in the bigger system (the roadmap) and what disruptions it causes in the system innovation chain and its subsystems innovation-chains. For example, are the suppliers of the system influenced by the innovation (backward integration), or the customers (forward integration), or makers of other elements and subsystems (lateral integration).

The search conference is first employed in order to articulate the desired elements of the system as a synthesis of the co-innovation’s member’s visions (*workshop 1: shared perspectives*). An analysis of the forces that could impact the system is provided in *workshops 1: shared perspectives, 2: Context scenarios, 3: Industry Perspectives*. Their lawful relationships of these forces to the system are mapped within contexts scenarios during *workshop 2*: *context scenarios*. The value propositions to achieve the visions are formulated and mapped as concrete system outputs, and the interrelated set of actions and resources needed for the roadmaps completion whether people, organisational, political, technical, legal, economic, social (system inputs) are articulated and mapped during *workshops 3:Industry perspectives & 4: Initial roadmaps* as system inputs. Finally, during *workshop 5: stress-testing initial roadmaps*, the system’s inputs and outputs are a) stressed-tested against the context scenarios and b) against the wins and losses of the co-depending actors in the system via aligning and mapping of such wins and losses. Sharing experiences via socialising, negotiating, synthesising and combining knowledge through dialogues and conceptual modelling; and reflecting on knowledge through synergetic actions are the key elements used in the above described process. Dynamic Roadmapping applied the Adner’s model of ‘innovation blueprints’ in *workshop 5:‘stress testing initial roadmaps* in order to model and align the actors contributions needed for the successful implementation of the roadmap. Therefore, a good understanding was achieved of the several aspects related to the distribution of uncertainties, tensions, and contexts across different partners and other actors (e.g. adopters of the innovation) involved in realizing the value propositions and functional jobs of the roadmap. ‘Dynamic Roadmapping’ integrated the foresight methodologies in order to overcome the linear nature of Adner’s model based on traditional supply chain management. The cartography, weak signals analysis, scenario planning and innovation blueprints are all contributed to monitor, model, analyse and manage the uncertainty aspects that could impact the co-innovation roadmaps and provided the necessary alerts in order to make informed decisions towards the realisation of the roadmap solutions. The check list of the FSC ARE-IN principles also provided a good approach for making sure that in all cases, all the necessary actors were involved in all stages of the dynamic roadmapping.

Use of Conceptual Modelling

Since the co-innovation group included many diverse multi-disciplinary groups of stakeholders, which represented several social systems (i.e. political, research, business, technical, etc.), a systems approach which models the views, action designs and assumptions of these social systems was used. Models were employed as tools to describe or explain a system (e.g. vision statements, roadmaps) or as decision making tools that foreseen events and actions (context scenarios, 'innovation blueprints') (Flood 2010). This involved coding and abstraction (modeling) of information and the analysis by the co-innovation members and by the observatory network. The participants had the opportunity to use conceptual modelling in order to compare, map, contrast and extend the initial results produced during the workshops events. In doing so, both the participants and the observatory were assisted by a modelling team four people headed by the researcher. In addition, the facilitation team, the observatory gate keepers and its modellers were supporting and facilitating the co-innovation's participants modelling work. The collaborative conceptual modelling techniques employed utilised free conceptual modelling web tools (i.e. Conzilla browser and CmapTools). The use of conceptual modelling tools proved a very successful approach in order to extend the collaboration of the face to face events. In addition, it helped the co-innovation members to agree on concepts and their relationships, and then extend them and updated them, either during online in a synchronous mode using skype meetings, or offline by creating their own versions and then sharing them with the group. It also enables the observatory to add their alerts and comments directly in the co-innovations contexts maps, therefore provide targeted input and recommendations.

Conceptual modelling proved to involve a significant learning curve for both the co-innovation group and the observatory participants. Special online seminars headed by a senior modeller were scheduled in order to familiarize the participants with both the conceptual modelling techniques and with the related tools Conzilla, Confolio and CmapTools. This was necessary in order to encourage the participation of all stakeholders in the modelling excersise. In addition, skype meetings were scheduled with the modelling team in order to capture the ideas, concepts and relationships of the members who had no time or motivation to use the modelling techniques.

Another challenge the co-innovation group faced was how to go further in the representations. CmapTools are two dimensional and is difficult to show the hierarchy of the concepts and their specific contexts. For example, at each of the identified Actor-roles, decisions should have been made regarding both the route to adoption and the potential impacts of change, which needed to be mapped. The Adner model was later used in *workshop 5: stress-testing initial roadmaps* to deal with these problems, and prepare the *'innovation blueprints'*.

7.5 Reflections on 'Dynamic Roadmapping' by the TEL-Map Co-innovation group: Limitations and Strengths from lessons learned

As mentioned in section 6.6.5 *workshop 5: Stress-testing initial roadmaps,* the last session of this workshop was dedicated to an open discussion with the Co-innovation group in order to validate their experience and plans for continuations.

The following statements were the basis for this discussion:

- Do you value your engagement in the co-innovation roadmapping group?
- Do you value the roadmapping process?
- Did you value the outputs of this process?
- Would you like to continue working together with the group?

All the participants (about 80 people) agreed that they valued their engagement in the co-innovation group and they found the process very valuable and an excellent opportunity to form a community of practice in order to collaborate together and contribute to the development of TEL in schools sector. They found the interactive workshops and networking as the most valuable activities.

Some of them expressed their concern that the time for the interactive workshops was a bit limited, especially for *workshop 1: shared perspectives*, which they would have liked it to last two days instead of one. Some also commented that due to this time limitation, their streams of thoughts were interrupted. This comment was in line with the principles of the 'Future Search' workshop which usually last from 3 days to a week. A suggestion to solve this problem was that the brainstorming and ranking of the factors affecting TEL could have been done via web collaboration before the workshop. They all also appreciated the possibility to further the workshop results during the follow up online consultation activities. Also this approach was very beneficial for the co-innovation members that they could not attend the face to face workshops.

They also find the observatory activities very useful throughout the process of developing the roadmaps. In addition, they all agreed that developing bottom-up cartographies for the domain is one of the most crucial aspects in developing the sector roadmaps. The issue of the cartography was discussed in detail.

One participant suggested that they should put in place "meetings of programmes" which have similar aims and target groups, as well as set in place systems for collaboration. Based on the principle that the outcomes of projects which are funded with public money should be available to everyone, he stated that we should be looking for solutions and not projects, working "beyond the projects" by adopting the concept of "sustainability through co-innovation partnerships".

The idea of "European learning innovation cartography" was further described, based on a "living map of innovation" where the co-innovation group collects projects' outcomes targeted to a specific category of users. The ongoing cartography developed during the TEL-Map Roadmap was considered as the starting point for these activities.

A parallel was made to the European funded TEL R&D projects, which until today are driven by subsequent new projects until a new idea is coming up, which kick-starts a new cycle without a real integration of the previous results.

Funding issues

All participants agreed that they would have liked to continue their collaboration. They also agreed that some funding at least for their trips would be required. Some of this funding could be contributed by their organisations but additional funding would be required from Policy makers in order to sustain the cartography and observatory activities.

In addition, they argued that the decrease of research funding in national and EU research, makes the need to look for synergies across projects and innovative communities more relevant. It was stated that the European Commission should consider different more long term instruments in order to help projects to have a real impact, since a project on its own cannot provide a sustainable solution to complex innovation domains. Sustainability looks more promising through co-innovation partnerships that involve all the main innovation eco-system stakeholders. A suggestion was made to the EC to try to fund longer-term projects. The TEL innovation cartography can be used as a tool to avoid double-funding, and to support users to find a way to link to other associated projects. One participant stressed that, the cartography should be a map indicating the existing pitfalls and goldmines: “we need to be able to recognise the goldmines and then to “build villages” around them, not just to use and spoil them, and we need to be able to recognise pitfalls. The cartography should be able to show results, networks, innovations, to “defragment” funding and to collect results and knowledge”.

Finally, the participants agreed that the road to success for TEL innovations depends, to a large extent, on the possibility to be understood and supported by some categories of stakeholders that are not always the same (e.g. industrial investors, school leaders, publishers, policy makers, teachers’ networks, student associations, consultants, et cetera). Not all of them might ultimately influence every kind of innovation with similar leverage, but it is important to consider the full spectrum of involved interests and to bring together the most crucial representatives of stakeholders to support the innovation development. Furthermore, what appears a big success in a certain context may not work at all in another context (e.g. country, socio-economic environment, organization, or sector). It is therefore fundamental to identify not only “what works” but also “where” and “under which conditions”, distinguishing between success factors that are relatively “unique”, specific to the context, and others that can more easily be found or reproduced in other contexts.

Chapter 8: Conclusions and Recommendations for further research

Chapter 8 first provides a summary of the main contributions of this research work, which were analytically discussed in previous chapter, and then provides an overview of the main conclusions including recommendations for further research.

This research work provides new insights on issues of applied roadmapping and advances the state of the art in roadmapping and its practice. It advocates the development of new *meso-level dynamic roadmaps* via sector focused ***co-innovation groups***. It offers new conceptual models and practical step by step processes for developing **3rd generation 'meso-level'** 'Dynamic Roadmaps', appropriate for the development and management of complex systemic innovations. All actors involved in the innovation process are brought together and agree to develop, co-ordinate and realise their desired planned futures. The researcher has adapted theory and methodologies already existing from many fields and provided *an integrated new model and process framework.*

The new introduced concepts are:

- The concept of 'systemic Foresight' based on actionable implementation.
- The concept of 'meso-level' multi-organisational roadmapping.
- The 'co-innovation' aspect via stakeholders' collaboration and the establishment of the 'co-innovation' group.
- The concept of a 'Dynamic Cartography' for mapping the actors, their agreements and disagreements and the forces that could potentially impact the domain.
- The concept of an integrated Observatory as a 'dynamic insides tapping system' for the co-innovation group.

The impact of this research in practice is well demonstrating by the case study, as an application in action and in subsequent roadmapping endeavours and management innovation initiatives (e.g. CreAM[48] roadmap for creative industry, Open Discovery Space 'ODS' roadmap[49] for federated repository sharing at schools and HoTEL[50] innovation management model for TEL), in European and international conferences, workshops, and in dedicated European Commission Forums with stakeholders and policy makers (see also pp. 3 &5).

The practical implementation of the 'Dynamic Roadmapping' model also addresses the lack of a step by step approach for meso-level roadmapping at process levels. This includes systematic methodologies for the formation of the roadmapping co-innovation group, development of the desired futures, the roadmaps and the integrated observatory function.

[48] CRe-AM 'Creativity REsearch Adaptive roadMap' is an FP7 EU project, running from October 2013 to September 2015: http://www.cre-am.eu/
[49] Open Discovery Space: A socially-powered and multilingual open learning infrastructure to boost the adoption of eLearning resources: http://opendiscoveryspace.eu/project
[50] HoTEL (HOlistic approach to Technology Enhanced Learning) http://hotel-project.eu/

8.1 Main contributions of this research work

The main contributions of this research work are discussed below:

Literature review demonstrates that 'Meso-Level' innovation models and practices have not yet been adequately addressed by research and practice. The new 'meso level' approach developed in this thesis and applied in the case study is a key contribution to innovation management approaches, in terms of new applicable ways to develop and manage Dynamic roadmaps.

To unpack this further, 'meso level' Dynamic Roadmapping:

- Seeks to overcome limitations of earlier roadmapping initiatives, where *"experts"* produced roadmaps that were arguably not followed by others or were rapidly outdated by changing circumstances. To achieve this objective, this new approach provides models and processes in order to bring in, integrate and manage the existing and future needs, plans and *activities of stakeholder communities in the innovation process*. The success of the proposed approach is manifold: a) strategic planning is informed by local knowledge and contexts; b) the intrinsic motivation of the innovative communities to participate is increased, since they feel ownership and commitment to the outcomes; c) since a diverse spectrum of stakeholders are involved in the process, it is also assumed that a broader range of interests, topics, knowledge and information, as well as broader perspectives will be involved in the planning process.

- Extends both the current *top-down, market-pull, driven roadmapping approaches,* which are focused on incremental technological innovations from market to product to technology, and the current bottom-up innovation models, which advocate *linear trajectories* from an invention, to production, to the market. Therefore, Dynamic roadmapping provides a new approach for the development of systemic innovations that aims for radical and/or disruptive changes. Dynamic Roadmapping integrates foresight and roadmapping approaches in order to develop efficient systemic innovation processes which integrates the supply and demand side of thinking and also accounts for the social changes that can re-shape the innovations. This is done by linking the innovation process to: a) broader perspectives than the economic goals of competitiveness and growth and supporting the increasing requirement of systemic innovations to meet social and/or cultural needs; b) access to foresight (policy, research, and practice) intelligence via the integration of an 'Observatory Function' in the innovation management process.

- Extents the current innovation models based on the linear *thinking of traditional supply chain management*. This linear thinking of traditional supply chain management is not adequate when managing systemic innovations, which have multiple stakeholders on both the provider and adopter sides. Where an innovation is complex and requires a number of different players to develop it and bring it to market, and/or the market itself is complex, with multiple decision makers involved in each adoption process, the first and second generation of roadmapping methodologies are no longer effective. Individual company - *micro level* roadmapping is no longer sufficient on its own, even if all the partners required build the innovations individually and create and follow their internal roadmaps. They additionally need to be in close co-operation with the other players, with whom they will need to agree on desired futures, where they are headed, and coordinate and manage the diverse contributions, roles, and other inter-dependencies along the way of the implementation of their innovation plans. In addition, a *macro level* roadmap approaches does not specify how any particular group of organisations will work together to operationalise concrete innovations. Dynamic Roadmapping approach, overcome these issues by advocating a 'meso-level' innovation management approach. Such approach integrates adoption models in the innovation management process in order to map and align the needed contributions of suppliers, other co-innovators, intermediaries, and users. A continuous adaption and monitoring of the roadmap's context is also required in order to enable successful long-term adoption. Therefore, Dynamic Roadmapping employs foresight processes and an observatory in order to keep the adoption process dynamic and agile.

Consequently, innovation models and policy development are extended by moving from linear to iterative adaptive systemic innovation practices and from traditional forecasting methods to integrated actionable "systemic foresight" and roadmapping approaches.

Meso level 'Dynamic Roadmapping' concepts, models and processes contribute to the current research and practice of roadmapping by:

- Managing uncertainty in Future planning
- Managing and implementing emergent Roadmaps for systemic innovations
- Monitoring and adapt the produced Roadmaps according to change factors in emerging reality
- Ensure their adoption in complex domain

8.2 Conclusions and further research

This section summarise the main conclusions and provides suggestions for further research in order to overcome the limitations of this study.

8.2.1 Dynamic Roadmapping integrates the activities of different stakeholder's communities and forge their agreement to a common desired future.

In order to support the different innovative communities (e.g. policy, research, industry and practice stakeholders) to agree on shared desired futures, Dynamic Roadmapping employs a modified version of '*Future Search Method'* enhanced by several online sessions, collaborative modelling approaches, and web-based tools and shared documents. A Co-innovation group is formed from all necessary stakeholders in order to develop their shared desired futures and guide the development of agreed targets and roadmaps and their actionable implementation.

Previous roadmapping methodologies were based on top-down visions coming for example from an organisation's top-management goals, or from the agendas of policy and/or research groups. 'Dynamic Roadmapping' developed methodologies to ensure an organically emerged desired future that takes into consideration the diverse interests of the different domain stakeholders. Therefore, the interests, motives and actions of the innovative communities of stakeholders are brought in and integrated throughout the innovation process. Action participatory approaches based on Action research (FSC) were adapted for bringing the stakeholders together and articulate their desired futures. The suggested Dynamic Roadmapping approach overcomes several research and practice problems related to current participatory action oriented practices i.e. : a) the 'incompleteness problem' of bringing all the stakeholders who in between them have the power, information, resources, abilities and authority to achieve the planned innovations; b) the convergent thinking problem of only focusing on common grounds and therefore in superficial utopia futures; c) the problem related to manage disagreements and power structures.

This was achieved via the development of a combination of *bottom up and top-down approaches* in order to form and later enhance the initial Co-innovation group.

The bottom-up methodologies assisted in order to increase the internal motivation of the innovative communities to agree and collaborate towards desired futures and targets, because these futures were stemming from shared motives and objectives and not by forced or artificial consensus. A new *domain 'cartography approach'* is the core of these methodologies. The approach provides models, tools and processes to model the interrelationships among these different innovative communities in order to be able to: a) form mind liked groups to create the co-innovation roadmaps and agree on common ground and b) ensure the necessary resources for their operation. What brings together the innovative communities is *affinity*. The desire to work on the same problems and complement and enhanced their efforts to accomplice common purposes and targets. Thus, connections among the stakeholders exist within the same framework of reference and this is what will determine the successful collaboration and the determination to see through the realisation or their desired futures.

The cartography also presents a great opportunity to innovative communities to examine their assumptions about the effectiveness and efficiency of their existing and planned contributions and innovation approaches, and tests them and compares them with the plans and approaches of other communities, in terms of how others perceive those contributions. Therefore, comparing, contrasting and mapping the activities of the innovative communities and bringing together likeminded groups to form the co-innovation group.

The development of this cartography is achieved by:

- Modelling the voices of innovative communities, policy makers, users, industry players, practitioners and other influential stakeholders in the domain. An important aspect of this method is to go where the communities are and they interact (physically and online) rather than trying to organise separate events, or develop new platforms and tools that the communities must learn and adopt. This allows for capturing the innovative voices in their own events, within their own communities, trade fairs, conferences, meeting places and social networking sites, so that a true observation of their positions, assumptions, objectives and goals can be mapped. This also resolves the unrealistic approach of funding numerous stake holders consultations, where diverse stakeholders need to travel, spend time and money to attend them.
- Developing profiles and individual semantic portfolios for researchers, research projects, commercial innovation providers and organisations in order to facilitate the matching of likeminded and/or complementary actors. Interviews and modelling was used together with web-based semantic modelling tools (e.g. CmapTools, Conzilla browser and Confolio tools).
- Using surveys and Delphi studies and interviews in order to further map and analyse the input gathered from strategic conversations. Therefore, collaboration is driven by shared issues, objectives, activities and is based on common assessed needs.
- Using bibliometric and SNA techniques to provide further insights and identify new communities, practices, issues, innovations that might have not come up from the strategic conversations and Delphi exercises and that they need to be taken into account when forming the co-innovation group.

Top-down methodologies

Top-down methodologies are also provided in order ensure that *all necessary* stakeholders' roles and resources are included in the innovative communities that form the co-innovation group. For this purpose, the ARE-IN principles from the FSC and the innovation blueprints from Adner's adoption model have been adapted as ongoing working checking lists in order to provide recommendations as to who else is missing in order to implement co-innovation roadmaps.

Further R&D required

Limitations included the partial automation of both the profiling of innovative communities and the matching process for bringing collaborative clusters together. A common information architecture that semantically models and interconnects the different innovative communities and their activity systems as well as a knowledge management system is vital to this mapping process. New *collaborative web-based tools* for modelling and organizing the complex interactions between the innovative communities, their activities, motives, assumptions and objectives, their disagreements as well as their contributions in the co-innovation network must be further explored. New business models to support this type of extended networked organisations are also needed. Further research in search tools that can query the developed cartography and enable the finding of complementary innovative communities to start new co-innovation groups is also important. *Conzilla* proved to be a very good semantic modelling tool for such purposes, but it requires a steep learning curve. CmapTools is a more friendly to use tools but inferior in terms of functionalities to Conzilla. New big Data type of tools that would be easy to use would be more efficient.

8.2.2 Dynamic Roadmapping provides means to manage uncertainty in future planning: Integration of Policy/Foresight, industry and research.

Early models interpreted innovation as a linear sequence of activities starting from an idea, moving to pilot and then to commercialisation. At best, some feedback loops were included in-between this process. *One key challenge* for managing systemic innovations is the sense making of complex systems and the uncertain factors and drivers affecting these systems, whether technical, social, political or economic. This research work provides a very strong link between foresight and roadmapping in order to promote more efficient systemic innovation processes and take into account social changes and other environmental factors that can re-shape the innovations. This integration of foresight and roadmapping approaches makes sure that the roadmaps: a) are correctly positioned in both local and future contexts; b) are supported by a process in order anticipate and manage the opportunities and threats stemming from future surprises; c) and have potential for actionable implementation.

Therefore, Dynamic roadmapping provide models and framework processes that integrate different types of intelligence such as organisational (company), industry (sector), policy and research via an observatory function in order to provide information to Co-innovation group in the form of different intelligence streams such as: domains of change (Policy foresight); research and domain cartographies (research roadmaps); and state of play and value propositions (industry roadmaps). Therefore, it connects the different innovative roadmapping communities via the Co-innovation group and integrates their outcomes and roadmaps.

Exploratory scenario Planning is integrated in the roadmapping process in order to enable the co-innovation group to build a shared view of the transactional and wider (PESTLE) contexts that might impact the desired futures. This approach extends the foresight beyond technology assessment and establish significant high and low uncertainty factors, which can then be grouped and analysed in different context scenarios. The roadmaps are stressed test in each of these context scenarios and the diverse roadmap pathways and alternative strategies per pathway are identified. In addition, weak signals analysis is employed in order to make sure that the foresight approach is not restricted to the limited radar horizons of the co-innovation group as well as to include factors of changes that might not be desirable and thus tend to be overlooked or dismissed, by the co-innovation group.

Further R&D required

Further research in methodologies related to the *Big Data* technologies (such as text mining, bibliometric, SNA) is needed, in order to identify PESTLE changes and *automatically provide alerts* to the co-innovation group in the form of direct links to the associated parts of the roadmaps and their related contexts. *Intelligent Agent* technologies and predictive models using 'big data' analytics could also be used in order to perform *cross impact analysis* of several trends and assess possible solutions (e.g., assessing the cross-impact of technological developments). Moreover, the 'Autonomic computing' is a promising area of research in order to develop methods to reduce the amount of complexity and to intelligently make complex decisions based on large amounts of uncertain, heterogeneous data (Kamtsiou et al. 2014).

The development of an agreed terminology and graphical representation of roadmapping that works across the different Roadmapping types (Policy, industry, company, research) and levels (micro, meso, micro) would greatly facilitate their working together. This would then provide the basis for the development and interworking of interactive graphical tools that would make the development and integration of these types of roadmapping a much simpler operation. There is a plethora of such tools today. What is missing is the integration of existing web social networking tools, which are already used by the innovative communities. For example, tools for: collaborative writing (e.g. wikis and google documents); collaborative modelling (e.g. mind mapping, and CmapTools); online consultations (e.g. skype and adobe connect); community spaces (e.g. Linked-In and face-book); awareness building (e.g. tweeter, RSS feeds); content management and CRM (e.g., Confolio, wiki.teria, eportfolios); timelines development (e.g. MIT's Simile Timeline) and tools to integrate existing calendars. In addition, other type of tools need to be integrated which provide functionalities such as: Real time Online Delphi; weak signals analysis; cross impact analysis and Bayesian analysis; trend analysis; horizon scanning analysis; text mining; visualisation; social networking analysis; and disagreement management.

8.2.4 An observatory function keeps the roadmapping process dynamic and agile.

Given a relatively long, 8 to 10 years, implementation horizon, the planned pathways mapped in the roadmaps are not static, but they evolve and diverge. This is because of the increasing uncertainty in the roadmaps longer time future projections, which are associated with their wider transactional and contextual environments. In an increasingly volatile and turbulent operating environment, any initial roadmap needs to be adaptive to future surprises in order to stay agile and effective. Similarly the roadmapping process needs to allow for this continuous reviewing and adaptation of the roadmaps.

The *dedicated observatory function* provides the co-innovation group an insights tapping system and a proactive approach. Such approach supports the continuous review of internal as well as external factors in order to enable the co-innovation group to make informed decisions and agree on a range of possible changes, from minor to major. It scans and monitors current developments and identify how the uncertain, but plausible future scenarios are emerging in practice, and hence which of the alternative paths to adopt. The observatory function, when appropriate, reports back to the Co-innovation group on any changes in the transactional on contextual environments that that may impact on the group's roadmaps, current context mapping, future scenarios, goals, or desired future, in that order of increasing significance. The Co-innovation group considers the observatory feedback in terms of:

changing their targets e.g. if either one or more target prove infeasible, or other players do the required work independently, either requiring a revised roadmap; and revising the shared desired future. For example, if the world changes such that it is no longer so desirable, or if the partners either no longer desire the agreed future, or they evolve it into a more desirable future, requiring new goals and roadmaps, and possibly requiring revised scenarios if different factors and uncertainties become important. Therefore, the observatory function as an 'insights tapping system' amplifies the efforts of the innovation communities, ensures the efficiency and effectiveness of their innovation process and that such process remains relevant to the wider social contexts and ensures the evolvement and sustainability of their roadmaps over long term.

Further R&D: greater automation for Alerts

Meso level 'Dynamic Roadmapping' processes enable players to identify key trends and drivers, together with their uncertainties, that have the potential to make high impacts on their roadmaps. While this helps to identify the types of signs and signals for an observatory function to look out for, it is still a difficult task to identify early signs and project their potential significance. Further research to better understand this process and the development of related tools to enhance it in order to a) scan for change factors (e.g. trends, drivers, potential signs and signals); b) to provide their systematic observation and analysis in order to filter out the change factors that have potential significance to the co-innovation group; and c) to translate from significant identified signs and signals back to actionable alerts for the co-innovation group; would be of both great and general value. How to automatically provide alerts directly linked to the co-innovation roadmaps needs to be further investigated. Some important work has been done in this area in terms of mechanizing the process of updating the roadmaps based on observed changes on a set of drivers, such as (Strauss & Radnor 2004), (Vatananan & Gerdsri 2011), (Schoemaker et al. 2013), (Suharto 2013b).

8.2.5 Dynamic Roadmapping ensures the adoption of systemic innovations in complex domains

In response to the evolution of the Internet, globalization, fast technological advancements, and environmental pressures, we increasingly find that individual companies are no longer able to manage entire value chains internally working in isolation, but now often involve the co-ordination of multiple participants. The extreme examples are the creation of entire ecosystems of players, such as those involved in the Apple App Store, Google's Play Store or Amazon, but there are many other examples, such as in education, pharmaceutical, energy and educational domains, where a number of players are necessary for the successful adoption of an innovation, and others who need to co-innovate products and/or services, in order for the innovations to reach the final users. These players extend to include customers and buyers as co-creators and participants in the supply chain. During the roadmaps' implementation, all the innovation chain suppliers, intermediaries and end user/customers need to be involved, aligned and coordinated, particularly where the adoption on their part requires changes in practices and procedures. Therefore, a good understanding is needed of the distribution of uncertainties across different partners and other actors (e.g. adopters of the innovation) involved in realizing the value propositions and functional jobs of the roadmap in different local contexts.

Typically, both roadmapping and systemic innovation involve a lot of coordination of tacit knowledge, informal communication, and disagreement management, making the whole process a learning process. This is due to the non-linear nature of such innovations, which requires the involvement of many players and the need for their coordinated collaboration.

Dynamic roadmapping addresses the difficulty to make sense and analyse the significance of interconnection among the actors in the innovation process. It adopted the Adner's model of 'innovations blue prints' in order to facilitate the innovations adoption. Using this approach, 'co-innovation blueprints' are created for each design solution in the roadmap. Each of the actors that create and add value to the development, implementation and provision of the design solution needs to be identified in a value blueprint, in which their willingness to participate is simplified and represented as a green, yellow or red traffic light against each player. This assess the perceived benefits by the innovation chain actors (e.g. co-innovators and other intermediaries) in terms of whether: a) there are substantial benefits from the innovations, therefore, the actors are ready and willing to collaborate; b) there are neither benefit nor loses perceived, therefore it is uncertain whether the actors are willing to collaborate; c) there are perceived losses from the innovations, therefore the actors are unwilling to participate and they may even try to block the innovations. This analysis, informs decisions on required adjustment of the designs to redress their losing position, or a redesign so that they are no longer a key to success.

In addition, Dynamic Roadmapping' integrated the foresight methodologies in order to overcome the linear nature of Adner's model based on traditional supply chain management. The cartography, weak signals analysis, scenario planning and innovation blueprints are all contributed to monitor, model, analyse and manage the uncertainty aspects that could impact the co-innovation roadmaps and provided the necessary alerts in order to make informed decisions towards the realisation of the roadmap solutions.

Further R&D: Enhanced integration of change management in adoption of systemic innovation

Further R&R is required in order to develop the frameworks and practices needed to bring about constructive inter-working between innovation and change management. This includes new models in knowledge management, decentralised decision making management, and understanding of the entire functional logic and needed synergies or collaboration of the multiple innovation chains that need to be managed by the Co-innovation group. The lessons from open source consortia and open innovation models can contribute to these new practices. Finally, it should be further investigated how disruption in roadmapping plans (systemic failures) or breaks in quality of outputs can be managed within such the co-innovation networks.

8.2.6 Some overall limitations of the approach

Overall, the Dynamic Roadmapping process requires significant funding in order to: establish the observatory function, in terms of people, digital sources, and develop its services; cover the travelling costs of the co-innovation participants and the costs for hosting the co-innovation and observatory network meetings. Since, the roadmapping activity will usually require more than 7 to 10 years to be completed, from planning the innovations to their adoption, funding would be required as a regular streams over long period of times. It is therefore important to find sponsoring organisations (e.g. from Policy, research, NGOs, Charity groups, etc.) in order to sustain the process. Industry sponsors should be targeted carefully, since this might create competitive tensions with other industry players in the co-innovation group and disturb its internal power structures. A great intensive for the stakeholders is the fact that the synergetic effects stemming from the Dynamic Roadmapping process are having a great cost saving effect for the members of the co-innovation group, on the long run, in comparison to develop and manage innovations internally by the participants alone. In addition, such collaboration minimises costs and risks associated with the adoption of systemic radical and/or disruptive innovations.

Finally, this approach seems more difficult to be applied in cases that there is severe competition in the field among commercial players. For example, when the intended technological innovations provide a long term completive advantage such as in cases of pharma and weapon industries. Even in such cases, successful collaboration in co-innovation networks can be established by allowing some player to internally develop certain components of the innovation elements. A more in-depth study for the successful management of patents and Intellectual Property Rights, as well as modelled collaboration consortium agreements would greatly minimise such obstacles. This problem is a lot more manageable when the co-innovation groups consist of local stakeholders and the roadmapping challenge has a local context.

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