Applying structured methods to Eco-innovation. An evaluation of the Product Ideas Tree diagram

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Abstract

This paper reports on the first test of the Product Ideas Tree diagram (PIT): a structured method aimed to help Eco-innovation. The PIT diagram structures ideas output from chaotic idea generating sessions. This study compared four ways of conducting an Eco-innovation workshop. The results show that structured methods help Eco-innovation by improving the constructive communication between the participants. Further development of the PIT diagram promises to contribute several new approaches to sustainable product and process design.

Author Keywords: innovation; creativity; design tools; eco-design; teamwork

Eco-innovation is one of several approaches towards sustainable product design, which aims to provide customer and business value whilst significantly decreasing environmental impact[1]. Eco-innovation aims to develop *new* products and processes, which meet the *needs* of customers in the most Eco-efficient way. Sustainable product design is one part of a global movement towards sustainable development, which is driven by the realisation that society cannot continue current modes of production and consumption without serious ecological damage. One commonly quoted definition of sustainable development is 'development which meets the needs of a current generation without compromising the ability of a future generation to meet their needs'[2].

Sustainable product design requires the balancing of economic, environmental, ethical and social issues in product design and development. Sustainable product design requires creativity, innovation and the participation of many different actors such as policy makers, business strategists, managers, designers, engineers, marketing managers and consumers. Successful Eco-innovation relies upon the collaboration between these stakeholders.

Business strategies that include sustainable product design can improve a company's competitive advantage by supporting expansion into new markets, through the launch of new products with environmental attributes which consumers desire. Philips, for example, launched a range of 'green products' in 1998[3] and has had corporate environmental commitment since 1987 when they issued their first environmental policy. They have long regarded environmental care as a business opportunity, where the corporate 'Green Image' is of great value to the company both externally and internally [4]. Such an environmentally proactive company may also benefit financially from the optimisation of production processes, reduced material and energy use, and reduced waste generation.

In sustainable product design a discussion is emerging that focuses on the integration of environmental considerations into product development, taking account of the different environmental issues and concerns at different stages in the product development process[5]. Eco-innovation considers environmental aspects of the product at the early stages of the product development process, such as the strategic product planning stage or the new concept development stage.

A number of tools and methodologies have been developed to support the process of Eco-innovation. Streamlined environmental design tools such as the Life-cycle Design Strategy (LiDS) wheel[6] and the Eco-compass [7] condense environmental information into a visual map that displays the comparative environmental merits of new design options against the original design. Other tools such as the Philips STRETCH methodology [8] are specifically designed to support Eco-innovation at the early stages of the product development process. The STRETCH methodology consists of five steps, which help identify the most promising environmental opportunities. The STRETCH methodology aims to incorporate environmental aspects into the company's business strategy and helps anticipate future environmental opportunities and threats earlier.

None of the existing Eco-innovation methodologies focus specifically on the idea generation process. The LiDS wheel and Eco-compass can provide key-starting points to structure brainstorming sessions for Eco-innovations, however, their main use is as tools to *assess* the environmental merits of new product concepts. The STRETCH methodology prescribes brainstorming sessions at various stages, however, it does not describe the idea generation process specifically.

In order to get the most out of the idea generation process, the *activity* and the *outcomes* need to be structured. Tassoul conducted a case study, generating radical concepts for clean textiles in the context of sustainable development[9]. He suggests that it is not easy to summarise the outcomes from such creativity workshops and states the need for frameworks to help cluster results from workshops.

Much work has been done on the *activity* of idea generation, and many techniques have been developed and established such as: *Brainstorming*[10], *Lateral thinking*[11], and *Synectics*[12]. These techniques generally increase the productivity of participants by controlling the direction and quality of their thoughts [13]. However, relatively little emphasis has been made on structuring the *outcomes* from these techniques. Osborne suggests appointing a secretary to take down and consecutively number all ideas during a session. De Bono[14] discusses different methods of capturing ideas during the idea generation process. He states the need to extract and record the output systematically. He uses a checklist to group the ideas and proposes another classification technique to formalise different types of output. Hanks [15] acknowledges the importance of all participants being able to see the recorded ideas simultaneously during the session. He states that new ideas will be expressed as a result of being able to see the relationships between the ideas captured already.

Mind mapping[16] is one technique that can be used to structure the outcomes from creative sessions. Tony Buzan developed Mind maps as a way to generate and record ideas. They are diagrammatic representations of ideas, where all ideas are recorded as they radiate out from a clearly defined central idea that is clearly defined. Mind maps are now a well-established technique and can be used as a powerful graphic representation of the outcomes from creative sessions.

1. Problem statement

In general, idea generation within Eco-innovation uses brainstorming techniques similar to those used in conventional product development practice. However, in Eco-innovation the objectives and the key-starting points for brainstorming sessions emphasise improvement in product environmental performance and success in Eco-innovation relies on the collaboration between different stakeholders. Relatively little research has been done on the idea generation process within Eco-innovation.

To research and advance idea generation processes in Eco-innovation, a new tool has been developed, the Product Ideas Tree (PIT) diagram[17]. The PIT diagram helps structure idea generation activities and the outcomes from them. The PIT diagram is a specific tool that aims to overcome some of the communication problems between the different stakeholders at the early stages of the Eco-innovation process. These communication problems are similar to those published in a recent study [18].

This paper introduces the PIT diagram and reports on a pilot study of its use where the participants were asked to generate ideas for improving domestic dishwashing. The main aim of the experiment was to assist in the development of the PIT diagram as well as providing insights into better ways of testing such a recording tool. Previous research shows the merits of conducting formal evaluation studies into design tools[19]. These studies are able to offer qualitative insights into the ease with which methods are used as well as quantitative data on the performance of methods for comparative analyses.

2. Introduction to the PIT diagram

The PIT diagram is a novel method for clustering Eco-innovation ideas and documenting them clearly. The PIT diagram structures ideas output from chaotic brainstorming sessions by mapping these ideas onto a surface. The PIT diagram combines: some key-starting points for Eco-innovation, a hierarchical structure for ideas, and the Mind mapping technique to produce valuable documentation in the form of maps. Figure 1 shows a schematic of the PIT diagram with pointers explaining the way it is intended to be used. Also shown are the key-starting points for Eco-innovation used in this experiment.

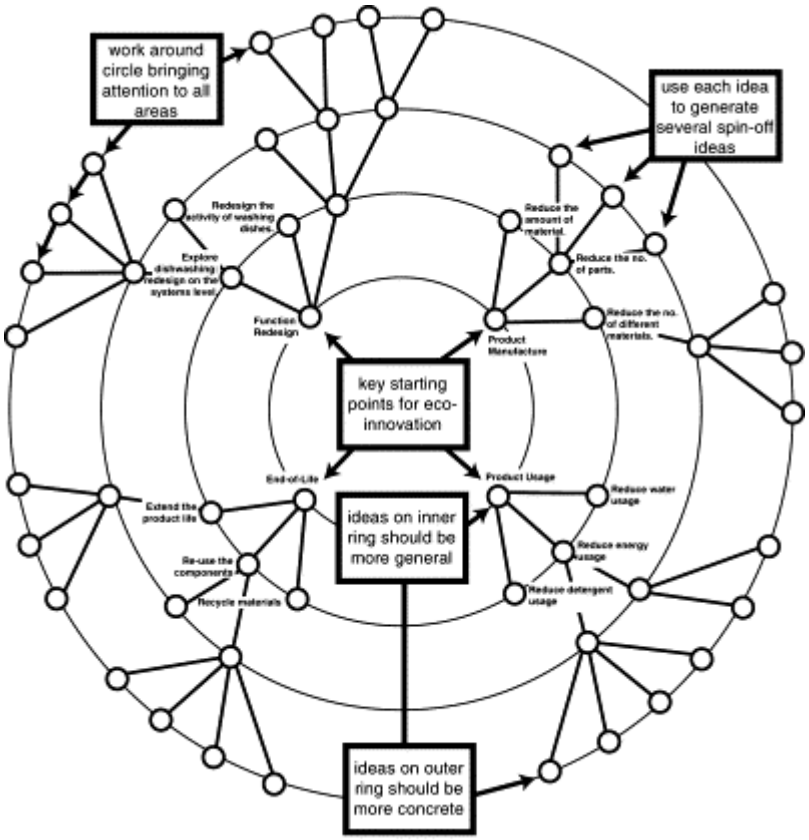

Figure 1. Schematic of PIT diagram with ‘pointers’ showing intended use

Owen[20] developed a hierarchical, clustering information structure that enabled design teams to represent the information needed in team synthesis sessions, but did not report research on optimising the output from such team sessions. The PIT diagram is different from any existing idea recording or ‘mapping’ technique because the ideals are simultaneously clustered according to some key-starting points for Eco-innovation and also placed within a hierarchical structure. Figure 2 shows an example of the PIT diagram used in a creative session, which was part of previous developmental research[21].

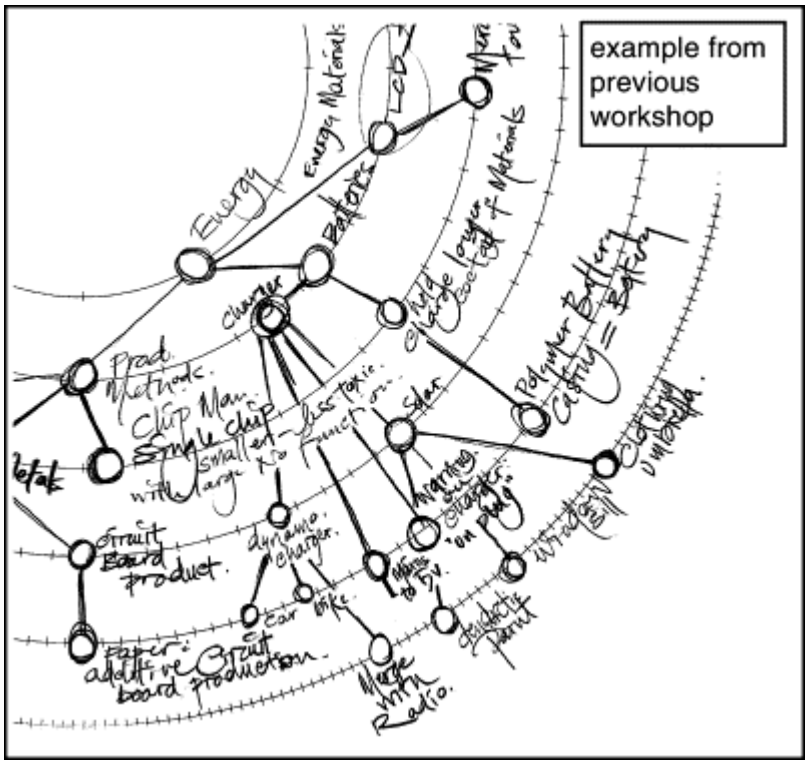

Figure 2. Example of the PIT diagram from an Eco-innovation workshop

It was therefore hypothesised that the use of the PIT diagram in a creative session would produce more ideas (H1), more environmentally relevant ideas (H2) and would help facilitate such a creative session (H3). These three will be treated as separate research questions for the purposes of data analysis and interpretation.

3. Methods

3.1. Participants

The 20 participants with mean age of 21 years were unpaid volunteers recruited from the final years of the following degree courses: Industrial Design (BSc), Industrial Design Engineering (BSc), Product Design (BSc), and Industrial Design and Technology (BA). These courses all have several core modules in common and in the final year the selected options determine the design specialisation for each of the students.

3.2. Experiment design

3.2.1. Independent variables

The aim of this pilot study was to test the PIT diagram, for which purpose we broke the PIT diagram down into the two main elements: the radial recording method and the key-starting points for Eco-innovation. Manipulated were these two between-subject factors: (1) the recording method (radial recording method and no method); and (2) the key-starting points (key-starting points for Eco-innovation and no key-starting points). Table 1 shows how these two factors were crossed yielding the four experimental conditions.

Table 1. The conditions allocated to the four groups

	no Radial recording method	***Radial recording method***
No key-starting points for Eco-innovation	**noE,noR**	**noE,R**
Key-starting points for Eco-innovation	**E,noR**	**E,R**

3.2.2. Dependent variables

To test the three parts of the hypothesis the following dependant variables were selected for each part.

Use of the PIT diagram produces more ideas (H1). Initial ideas (A): the number of ideas generated in first 15 min of the test, as recorded on the post-it notes. Expanded ideas (B): the number of ideas generated in last 15 min of the test, as recorded in felt-tip pens on the large recording sheet directly.

Use of the PIT diagram will produce more environmentally relevant ideas (H2). Environmentally relevant ideas: the proportion of the total ideas generated (A)+(B) which were judged by two environmental design experts to be environmentally relevant with or without possible rebound effects.

Use of the PIT diagram will facilitate the sessions and make them more constructive (H3). From video recordings of all the groups, the authors made general observations on key actions and approaches during the sessions. From the same recordings the last activity of the session (expanding the ideas for 15 min) was examined. Four different types of interactions were identified as the categories for analysis. The number of constructive, analytical, destructive interactions and queries in the session were counted.

3.2.3. Explanation of terms

Radial recording method: a method for recording ideas on a surface that links ideas and simultaneously places them in a hierarchical structure.

Key-starting points for Eco-innovation: the key-starting points (or brainstorm prompts) that were distilled from LiDS wheel and Eco-compass. These key-starting points were provided on two levels, as the headings and sub headings show below.

Product manufacture

Reducing the amount of material in the product

Reducing the number of parts in the product

Reducing the number of different materials in the product

Product usage

Reduce water usage

Reduce energy usage

Reduce detergent usage

End-of-life

Extend the product life, design for longer life

Re-use the components, design for upgradability

Recycle materials, design for ease of separation

Function redesign

Redesigning the activity of washing dishes

Redesigning the ‘dishwashing’ system

Environmentally relevant ideas: ideas that show potential to reduce the environmental impact of the product or system throughout its life cycle: from materials extraction, through production processes, packaging and transport, product use, to end-of-life disposal.

Environmental impact: detrimental effects related to the use of materials and energy and release of substances into the environment.

Rebound effect: where an (potential) environmental improvement at one stage of the product life cycle has a detrimental effect at another stage of the product life cycle.

Constructive interactions: all interactions that lead to new ideas output or build on existing ideas leading to new ideas.

Analytical interactions: all interactions that were constructive but did not lead directly to new ideas output, these included activities such as information summaries.

Destructive interactions: all interactions that slowed down the flow of new ideas output, these included activities where the participants failed to reach consensus or disagreed.

Queries: all interactions where the participants queried the methods, task or instructions, this also included all time keeping and hurrying along.

3.3. Procedure

3.3.1. Recruitment

The 20 final year students taking part in this experiment were recruited by personal invitation one week before the workshop was held.

3.3.2. Warm up session and grouping

The participants were divided randomly into four groups. To check the uniformity of design *skills* and design *interests* between each of the groups the following two analyses were undertaken.

For the first analysis, a profile of the participants' different final year options was undertaken. The authors grouped these options as humanistic options and technological options. Humanistic options were context, graphics and design-related studies. Technological options were all the science or technology options. The groups' profiles of design *skills* were made up by the total number of technological and humanistic final year options chosen by the members of each group.

The second analysis doubled up as the warm-up exercise for the session. Each participant was given 10 min to select two pictures from a large bank of different magazines that would depict their design interests. The participants were subsequently divided into the four groups and asked to paste together their pictures on a board. The authors counted the pictures on these boards and grouped them in the following categories: *Nature* (nature or natural products), *Society* (social comment or human activity), *Architecture* (atmospheric interior or social comment) and *Technology* (cars, high-tech products or highly styled products). The boards provided a profile of each of the groups' design *interests*. An example of such a board is shown in Figure 3.

Figure 3. Example picture board from warm-up exercise

Table 2 summarises the outcomes from these two analyses and highlights the number of participants in each group with Environmentally Sensitive Design (ESD) as a final year option. The authors were satisfied that the groups were adequately homogenous for this experiment.

Table 2. Summary of design skills and interests

	Profile of group design skills			*Profile of group design interests*			
	Number of selected final year options			*Number of images on board depicting*			
	Humanistic options	*Technological options*	*ESD* option*	*Nature*	*Society*	*Architecture*	*Technology*
noE,noR	9	6	2	1	1	5	3
E,noR	9	6	4	0	2	2	7
noE,R	7	8	4	1	4	1	7
E,R	9	6	4	0	2	3	5

3.3.3. Communal briefing

After the warm-up exercise, the groups were briefed communally on the task, the ideas outputs expected, the timing of the different activities within the session, the idea-recording techniques expected at each stage, the operation of the video cameras and timekeeping required.

The task was to generate as many and diverse ideas for improving domestic dishwashing. It was emphasised that the workshop was about recording the way the ideas were generated. The participants were asked to generate as many and diverse ideas as possible and not to criticise ideas or eliminate any ideas. The participants were introduced to some general facts about dishwashing and the dishwasher. Throughout the session they were free to generate ideas on the product (the dishwasher) or the activity level (dishwashing). Each group had a copy of these general facts in their separate session rooms.

The participants were asked to record their ideas throughout the sessions by writing each idea as a single phrase statement. They were asked to avoid compound ideas statements (multiple ideas presented as one idea), by splitting such ideas into several single phrase statements. If ideas were sketched they were asked to translate those drawings into single phrase statements. Each group had a copy of these idea-recording guidelines in their separate session rooms.

The participants were briefed on the basic session programme for the four 15 min activities. The activities and the idea-recording techniques expected at each stage were described as follows:

Self-briefing, 15 min. The participants were told that each group would have slightly different instructions to follow for the session. They would be provided with two overheads and one page of accompanying text. One participant would need to volunteer to project these overheads and read the text out.
Individual brainstorm initial ideas, 15 min. The participants were told that the next activity was to individually brainstorm initial ideas. They were asked not to discuss ideas with each other but to record all idea statements on separate post-it notes.
Group discussion sorting ideas, 15 min. The participants were asked to bring together all the post-it notes, create categories to group all the ideas and subsequently place their grouped post-it notes on the large sheet of paper. They were then asked to identify the most interesting areas on the large sheet to explore further in the next part of the session.
Group brainstorm expanding ideas, 15 min. The participants were asked to work together to generate ideas that would expand the interesting areas identified. One participant would use felt-tip pen to record all these ideas directly onto the large sheet of paper.

Finally, the participants were briefed on the operation of the video camera and told to start the recording as soon as they entered their separate session rooms. They were asked to appoint a timekeeper to ensure that the basic program schedule was maintained and any deviation from the schedule would be recorded.

3.3.4. Group-self briefing and conduct of the activity

In their session rooms the groups received two of four different instructional overheads and an accompanying text to read. These described the methods that each group was expected to employ. Table 3 shows which of the four overheads each group received in accordance with the four experimental conditions.

Table 3. Overheads provided for self-briefing

	no Radial recording method	***Radial recording method***
No key-starting points for Eco-innovation	**noE,noR**	**noE,R**
	'classical brainstorming' 'placebo'	'radial recording' 'placebo'
Key-starting points for Eco-innovation	**E,noR**	**E,R**
	'classical brainstorming' 'Eco-starting points'	'radial recording' 'Eco-starting points'

Classical brainstorming. The rules of 'classical brainstorming'[10] were taken as the 'no recording method' because all groups were expected to abide by these basic rules during the session. The basic rules are to suspend all criticism, encourage freewheeling and desire a large quantity of ideas.

Radial recording. For the groups using the radial recording method the first part of their session was identical to the other groups. However, in the second part of the session they were expected to mark their idea headings on the inner ring of their large sheet of paper which had been pre-marked with four rings. Ideas closest to the inner ring should be more general and ideas on the outer ring should be more concrete. In the final part of the session they were asked to expand the interesting areas on the sheet by using each idea to generate several spin-off ideas and by working around the circle to bring their attention to all areas on the sheet.

Eco-starting points. The groups that were provided with the Eco-starting points were asked to consider those starting points as design directions whilst generating ideas, but were asked not to rule out other idea directions. This was done to ensure that all groups would feel the same degree of freedom to produce ideas. The authors thereby tried to ensure that the total ideas count (A) would not be affected negatively by providing these key-starting points. The key-starting points provided are listed in Section 3.2.3.

Placebo. The placebo was an activity designed to occupy the groups that were not briefed with Eco-starting points. This activity would take roughly the same amount of time, but would not influence the group's behaviour. These groups were simply put in 'un-prepared' rooms and asked to arrange their furniture and hang their recording sheet on a convenient wall.

3.3.5. De-briefing

For the de-briefing session the groups came together with their ideas output. This enabled each group to compare their efforts if they wished. Each group was asked how they felt their sessions had gone and this informal feedback was recorded.

3.4. Equipment

All groups had the following equipment: post-it notes, pens, felt-tip pens, a large sheet of paper (1.5×1.5 m^2), the dishwashing fact sheet, the task sheet, a video camera, a stop watch, an overhead projector, two overhead slides and accompanying text. (noE,R) and (E,R) had four pre-marked rings on their large sheet of paper. (E,noR) and (E,R) also had Eco-starting points on pieces of card and blue tack to attach these to the large sheet of paper.

3.5. Data analysis

3.5.1. Use of the PIT diagram produces more ideas (H1)

Initial ideas (A) were counted from the number of post-it notes produced. Expanded ideas (B) were counted from ideas that were written in felt-tip pen on the large sheet. Many of these ideas (B) were restatements of initial ideas and only few were genuinely new ideas. Therefore, the ideas (B) were separated into two groups: restatements of initial ideas (B1) and genuinely new ideas (B2).

3.5.2. Use of the PIT diagram will produce more environmentally relevant ideas (H2)

Two environmental design experts categorised all the ideas statements (A)+(B), they had to judge the statements to be either environmentally relevant ideas (with or without possible rebound effects) or ideas which were environmentally irrelevant or detrimental. An inter-observer reliability check was performed which revealed a moderate, and statistically significant, correlation between the two environmental design experts (rho=0.47, p<0.001). A cautious approach was taken with these data and only where both environmental design experts agreed that the ideas were environmentally relevant with or without possible rebound effects, were they counted (C). The rest of the ideas (D) were discounted (D)= ((A)+(B))−(C). The chi-square test was undertaken to test the difference between the conditions (noE,noR), (E,noR), (noE,R), (E,R).

3.5.3. Use of the PIT diagram will facilitate the sessions make them more constructive (H3)

The video recordings of the last activity of the session were analysed by identifying four different types of interactions, and counting their frequency. Previous studies of team interactions have used this sort of analysis[22]. The four types of interactions identified were the number of constructive (E), analytical (F), or destructive interactions (G) and the number of queries in the session (H). To add to the quantitative data in this pilot study, the authors watched the complete video recordings and made general observations on the actions and approaches taken by the groups.

4. Results

4.1. Quantitative data

4.1.1. Use of the PIT produces more ideas (H1)

Table 4 presents the initial, expanded and total idea counts from this study and reports on the quality of the expanded ideas.

Table 4. Initial and expanded idea counts and row percentages

		A: initial idea	*B: ideas expanded*	*Total ideas count*	*B1: re-statements*	*B2: genuinely new*
noE,noR	*N*	132	21	153	21	0
	Row (%)	86,30	13,70	100	13,70	0
E,noR	*N*	75	20	95	16	4
	Row (%)	79,00	21,00	100	16,80	4,20
noE,R	*N*	94	18	112	12	6
	Row (%)	83,90	16,10	100	10,70	5,40
E,R	*N*	86	5	91	2	3
	Row (%)	94,50	5,50	100	2,20	3,30

The PIT diagram is designed particularly to assist in the *expanding ideas* part of the session; (noE,R) and (E,R) were therefore expected to produce more expanded ideas (B). However, in Table 4 we can see that (noE,noR) and (E,noR) produced most expanded ideas.

When examining the quality of the expanded ideas, it was found that many of these ideas (B) were restatements of initial ideas and only few were genuinely new ideas. The ideas (B) were classified as either restatements of initial ideas (B1) or genuinely new ideas (B2).

From Table 4 we can see that (E,noR), (noE,R) and (E,R) produced some genuinely new ideas, but (noE,noR) produced no genuinely new ideas (B2). This might indicate that all groups with some methods performed better in this aspect than the 'no method' group.

(E,noR) and (noE,R) also had a relatively high proportion of their output in the expanding of ideas part of the session (B). The row percentages show that (E,noR) and (noE,R) were the most productive groups in this part of the session, scoring 21 and 16.10%, respectively.

4.1.2. Use of the PIT will produce more environmentally relevant ideas (H2)

Table 5 presents the results from the two environmental design experts: the number of environmentally relevant and discounted ideas, as well as the row percentages and expected values.

Table 5. Environmentally relevant and discounted ideas, row percentages and expected values

		C: env. relevant ideas	*D: discounted ideas*	*Total ideas count*
noE,noR	*N*	113	40	153
	Row (%)	74,00	26,00	
	Expected values	*96.35*	*56.65*	
E,noR	*N*	59	36	95
	Row (%)	62,00	38,00	
	Expected values	*59.82*	*35.18*	
noE,R	*N*	55	57	112
	Row (%)	49,00	51,00	
	Expected values	*70.53*	*41.47*	
E,R	*N*	57	34	91
	Row (%)	63,00	37,00	
	Expected values	*57.3*	*33.69*	
		284	167	451

Providing the key-starting points for Eco-innovation was intended to help the groups produce more environmentally relevant ideas throughout the session, (E,noR) and (E,R) were therefore expected to produce more environmentally relevant ideas (C). However, Table 5 shows that (noE,noR) produced most environmentally relevant ideas. This led the authors to look at the proportion of the ideas which were judged to be environmentally relevant.

The chi-square (χ^2=19.891, p<0.001) test showed that the observed frequencies differed significantly from the expected values. This meant that the generation of environmentally relevant ideas (C) was affected by the independent variables, allowing us to draw conclusions about the four different conditions.

Table 5 shows that (E,noR) and (E,R) produced only an average proportion of ideas that were judged environmentally relevant, 62 and 63%, respectively. (noE,noR) had the highest proportion of ideas that were judged environmentally relevant (74%).

4.1.3. Use of the PIT will facilitate the sessions and make them more constructive (H3)

Table 6 shows the results from counting the four different types of interactions in the last activity of the session and their row percentages.

Table 6. Interactions counted and row percentages

		E: constructive interactions	*F: analytical interactions*	*G: destructive interactions*	*H: queries*	*Total interaction count*
NoE,noR	*N*	48	54	11	15	128
	Row (%)	37.50	42.20	8.60	11.70	
E,noR	*N*	64	28	1	7	100
	Row (%)	64.00	28.00	1.00	7.00	
NoE,R	*N*	74	20	1	9	104
	Row (%)	71.20	19.20	1.00	8.60	
E,R	*N*	47	22	2	20	91
	Row (%)	51.60	24.20	2.20	22.00	

It was hypothesised that the PIT diagram would help facilitate creative sessions by providing structured visual output which communicates progress to all participants in the creative session, (noE,R) and (E,R) were therefore expected to work more constructively. The authors were expecting to record a higher number of constructive (E) and analytical (F) interactions for these groups. However, Table 6 shows that (E,noR) and (noE,R) were most constructive and (noE,noR) was most analytical.

Table 6 shows that (E,noR) and (noE,R) had the highest proportion of constructive (E) and analytical (F) interactions, 92 and 90.4%, respectively. This is supported by the qualitative data summarised in Table 7.

Table 7. Actual times taken and summary of observations from watching the video recordings

	Self-briefing	*Individual brainstorm initial ideas*	*Group discussion sorting ideas*	*Group brainstorm expanding ideas*
e(noE, noR)	9 min 45 s	15 min 35 s	30 min 15 s	17 min 27 s
	Individually read the 2 original briefing sheets	Ideas generation slowed down seriously after 10 min	After 3 min, groupings are created without much discussion or conflict	More constructive interactions and consensus
	Missed the 'brainstorm' overhead but did read out text		After 15 min, ideas had been grouped, confrontational discussion on doubles and meanings	Two members recording consensus ideas from existing ideas
			After 20 min, filtering and failing to reach consensus did not identify 'interesting' areas to expand, but left 'sensible' ones on the large sheet	Two other members expanding ideas in *discussions which were not recorded*
(E, noR)	12 min 33 s	14 min 01 s	21 min 40 s	13 min 40 s
	First few minutes some general unrelated chat	After 5 min 30 s, completely stopped generating ideas, chatted about kitchen-related objects and anecdotes for 6 min 30 s	Grouped ideas for 8 min 30 s by calling out: 'has any one got?' *very constructive*	Interesting areas chosen 'function redesign' and 're-design on the systems level'
	Individually read the two original briefing sheets	Last 2 min disciplined themselves to generate two more ideas each, some discussion on whether 'stupid' ideas counted	After 10 min, awareness of identifying most interesting areas	Recorder hesitant to take down new ideas, members confirmed: 'yes, we can expand'
	Tried to fill up time, read out the dishwashing briefing sheet to the group		Had *not* named their groups but agreed on: 'styling concepts' and 'washing concepts'	Several ideas successfully expanded but *only sensible ones taken down*
			After 17 min 30 s, started fitting Eco-starting point cards to their groups	About three other *new ideas missed*
(noE, R)	11 min 05 s	15 min 08 s	30 min 32 s	14 min 18 s
	Read out information on the overheads, without text	Ideas generation slowed down seriously after 10 min	Duplicate post-its were removed by the group: lost *at least 6–10 initial ideas*	Realised there was another activity
	Read out the two original briefing sheets	Persisted with individual ideas generation for another 5 min	Groups were easily determined, ideas on boards first, individuals called out for consensus	Explained to the camera: the hierarchy, overlapping boundaries, inside vague *generic*, outside implement
	Read out the text to go with the overheads		After 15 min 30 s, started using sheet, agreed on hierarchy, slow tentative placing of ideas	*Great ideas expansion due* to statements as: 'so, could we have···?' and 'just keep going round'
	Confirmed scope of ideas 'we do not have to be environmental about this'		Increased participation as time started to run out	*One expanded idea missed* on the sheet
(E, R)	10 min 56 s	14 min 49 s	29 min 04 s	19 min 11 s
	Read out text with over heads, spent some time individually ingesting the information, little discussion	Ideas generation slowed down seriously after 8 min	Laid out post it notes, grouping very slow and low key, no debates	Very low motivation, very little chat about the ideas only about the method highlighted the interesting ideas and raised that they still needed to expand them
	Read out the two original briefing sheets	Persisted with individual ideas generation for another 7 min	Force fitted their groups with the headings on the cards after 20 min placed the cards and groups on the sheet, copied the overhead layout	In the last 2/3 min, they took down some expanded ideas, two not recorded
			One member used the radial structure but did not communicate *understanding* to other members	At least one idea not *recorded* in felt-tip pen

All groups that had some methods (E,noR), (noE,R) and (E,R) had very low proportions of destructive interactions (G) 1, 1 and 2.2%, respectively. By comparison, the (noE, noR) group had a high proportion of destructive interactions (8.6%).

The group with both methods (E,R) had a particularly high proportion of method, task or instruction queries (22%).

4.2. Qualitative data

The qualitative data in this study has been invaluable for providing insights into the methods used in this experiment as well as providing explanations for the unexpected results in the quantitative data.

Table 7 summarises the notes made by the author whilst watching the complete set of video recordings. Some of the key observations are underlined. The four columns represent the four activities of the basic session program described in Section 3.3.3. Each activity was intended to take 15 min. Table 7 also reports the actual times taken for each activity.

The most important observations from watching the video recordings were:

All groups had excess time in the self-briefing and individual brainstorm parts of the session.

All groups were short of time and struggled in the 'group discussion sorting ideas' part of the session.

All groups missed recording some ideas in the last part of the session, this meant that the expanded ideas (B), (B1) and (B2) counts were affected.

Specific group-related observations were as follows:

(noE,noR) had most arguments and problems reaching consensus. However, they were the most dynamic, unconstrained group and produced the largest quantity of ideas.

(E,noR) worked very constructively as a team, although they missed a lot of their output on the large sheet. This may have been due to their hesitant recorder.

(noE,R) were disciplined and worked very efficiently throughout the session. They were particularly successful at creating genuinely new ideas during the expanding ideas part of the session. This may have been due to the good facilitation by their recorder.

(E,R) was the least dynamic group, they interacted least and did not debate or communicate much amongst themselves. They were the only group that seemed to find the session a chore.

5. Discussion

5.1. Evaluation of the experimental hypotheses

5.1.1. Use of the PIT diagram produces more ideas (H1)

Unexpected results for this part of the hypothesis were the particularly high ideas score (A)+(B) of the 'no method' group (noE,noR) and the low total ideas score of (E,R) who had both methods. (noE,noR) may have felt least constrained due to the absence of any special methods and (E,R) may have felt over-constrained by method instructions. The groups with some methods (E,noR) and (noE,R) were most productive in the expanding of ideas part of the session. Their tools may have provided an appropriate level of structuring for this session. This means that providing too many structured methods may inhibit the quantity of ideas produced.

5.1.2. Use of the PIT diagram will produce more environmentally relevant ideas (H2)

All groups produced notably high proportions of environmentally relevant ideas. A high number of participants were trained in (ESD) (see Table 2) and had, by coincidence, completed their final exam in ESD on the morning of the experiment. Group (noE,noR) were not constrained by any specific methods and may therefore have used more of their thoughts from the morning, this may explain their high proportion of environmentally relevant ideas. Providing the key-starting points on cards may therefore not have provided any extra advantage to (E,noR) and (E,R). This means that providing environmental prompts offers no advantage for producing environmentally relevant ideas, when the participants have already been trained in ESD.

5.1.3. Use of the PIT diagram will facilitate the sessions make them more constructive (H3)

(E,R) scored fairly low in the proportion of constructive and analytical interactions (E)+(F) and fairly high in the proportion of method, task or instruction queries (H). This suggests that (E,R) may have felt over-constrained by method instructions. Complex methods seem to give rise to more queries—this may be an artefact of the participants' inexperience with the method, and may be reduced over time and with practice. This experiment did show that all groups with some methods (E,noR), (noE,R) and (E,R) had very low proportions of destructive interactions (G). This means that providing structured methods reduces the number of destructive interactions in the groups.

Increasing the sample size would help determine whether the level of constructive communication was associated with the group dynamics or the four manipulated conditions. The qualitative data helped provide explanations for the quantitative data. The qualitative data highlighted a number of factors that may have influenced the use of the methods. The groups all had different interpretations of the instructions and different levels of discipline. There were too many instructions to be remembered by the participants throughout the session. The groups tended to deviate from the basic session program and violate some of the session rules unless there was at least one participant referring back to the overheads or the task sheet. Discipline in time keeping also varied between the groups. Some groups cut themselves short whilst still expanding ideas, whilst others worked on until the ideas ‘ran dry’.

Perhaps the largest factor influencing the expanded ideas count (B) was each groups appointed ‘recorder’: how effective were they at taking down the groups' ideas; how enthusiastically did they facilitate in the last part of the session; and how well did they understand the methods they were using?

5.2. Benefits of the PIT diagram

The PIT diagram did produce a relatively high number of genuinely new ideas in the last part of the session. The period after the flow of initial ideas has ‘run dry’ is a difficult time in idea generating sessions. The PIT diagram seems to be a useful tool at this stage. The groups with the PIT diagram also produced a high proportion of environmentally relevant ideas. The diagram's visual structure may have made the groups more aware of which ideas would lead to environmental improvements in the products, highlighting which ideas would need to be pursued further for Eco-innovation.

Those groups with methods in their sessions had a particularly low number of destructive interactions. Using structured tools, such as the PIT diagram, in creative sessions does improve constructive communication between the participants.

5.3. Problems encountered testing the PIT diagram

The complexity of combining the radial recording method and the environmental starting points may explain some of the difficulties encountered by the (E,R) group. This could be improved by simplifying the tool or its instructions. Alternatively, the PIT diagram might be used more successfully if one member of the team was trained in the use of the tool, thereby freeing up other members of the team to simply generate ideas.

When used in creative sessions the PIT diagram with key-starting points for Eco-innovation is designed to provide a great *span* of potentially environmentally relevant ideas. Therefore, counting the number of ideas was perhaps not the most appropriate data to collect. A dependent variable that said something about the spectrum of ideas would be more useful. Judging the environmental relevance of ideas could also be improved. The environmental relevance criteria need to be developed further to help judge to what *extent* the ideas are environmentally relevant, thereby providing richer data about the performance of the tool.

This experiment used a typical brainstorm sequence of activities: individual brainstorm on post-it notes, grouping ideas, and team generating ideas. This approach may have restricted the use of the PIT diagram. The PIT diagram should allow participants to expand ideas from key-starting points, and create a span of ideas that radiate across the whole surface of the diagram. The excess time in the individual brainstorm part of the session, meant that unmanageable numbers of post-it notes were created. The large number of post-it notes made the grouping of ideas very difficult. The rings of the PIT diagram became over-crowded and confused. Figure 4 shows an example of the over crowding of post-it notes on the large sheet of paper.

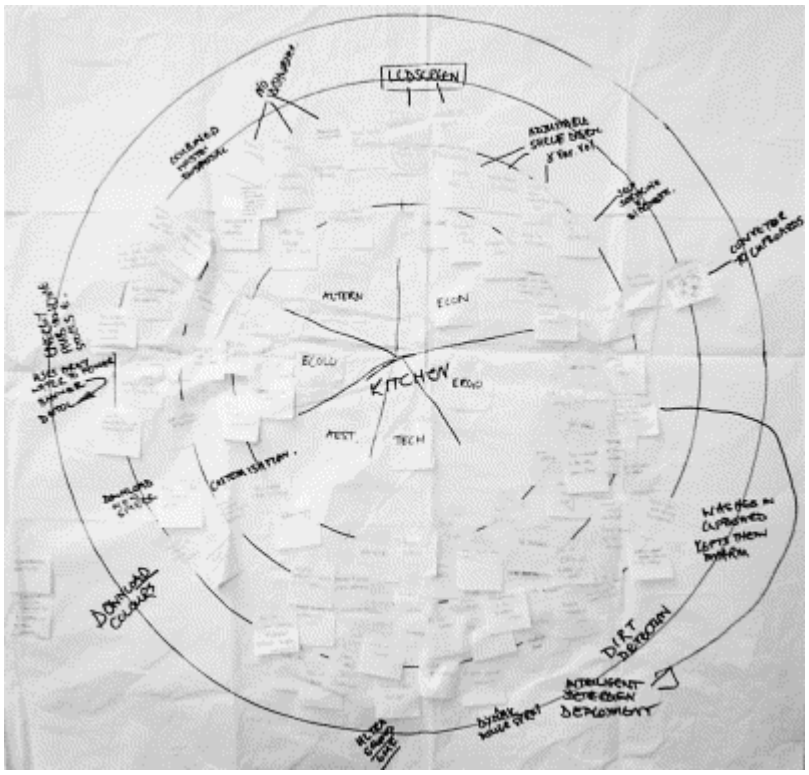

Figure 4. The over crowding of post-it notes on the large sheet of paper (noE,R)

In future experiments the PIT diagram would not be tested using a typical brainstorm sequence of activities. The first activity 'individual brainstorm ideas' would be limited or cut out completely. The groups using the PIT diagram would have a large sheet with pre-printed rings and key-starting points, and be allowed to record directly onto the sheet, similar to examples previously published[17].

The video recordings revealed a reliability problem with the data recorded on paper by the groups: some post-it notes were 'lost'; some groups slipped into the habit of filtering or eliminating ideas even though they had been briefed not to; many expanded ideas were not recorded at all; many expanded ideas were not recorded in felt-tip pens thereby confusing the ideas counts (A) and (B). In future experiments the data could be collected by trained observers or recordings could be analysed to provide more reliable data.

5.4. Further development of PIT

Since conducting this experiment, the same dishwashing task was set to a different group of participants, in a less controlled environment. All groups were briefed communally on the use of the PIT diagram, with an opportunity to ask questions, ensuring a full understanding of the method. They were only given 3 min for the initial ideas stage and asked to produce only four or five post-it notes each. Each group in this small trial successfully grouped their ideas and placed them in hierarchies on the rings of the PIT diagram. They successfully expanded ideas in a very short time. The quality of ideas that came out of this 20 min session were very similar to those recorded in this experiment, which took over an hour. This informal study shows the benefit of ensuring that participants fully understand the workings of the method.

In parallel to the study reported here, the use of the PIT diagram as documentation of the design process is also being investigated. From observing designers using the PIT diagram on their own (i.e. without a team), the authors discovered that the ideas on the PIT diagram are often alternating between problem and solution statements. These observations question the use of the method in idea-recording and indicate an alternative use. A more powerful use of the PIT diagram might be to help teams break down a design task by defining problem hierarchies. These problem hierarchies would facilitate Eco-innovation sessions by providing points of reference for all the different stakeholders in the process.

6. Conclusions

This study shows that structured methods assist participants in generating environmentally relevant ideas in creative sessions by improving the constructive communication between the participants. The PIT diagram improves the ability of groups to produce ideas after initial ideas have 'run dry'. However, if the PIT diagram is going to specifically address the

communication issues between different stakeholders in Eco-innovation process, then in future the tool must be tested with participants from different disciplines.

This research also identified some potential problems with the PIT diagram such as the danger of 'over-structuring' idea-generation sessions. This 'over-structuring' may cause the participants to feel like they are working on a chore. Also, unfamiliarity with the new tool may slow down the idea-generation process.

The PIT diagram offers a promising new approach for idea-generating sessions: enabling groups to work together from the start of the session, removing the need for individual initial brainstorm ideas. The PIT diagram also shows the potential to help generate radical new concepts for Eco-innovation in relatively short idea-generation sessions. However, this research also identified shortcomings in the testing methods used in this study. In future experiments: the participants will be trained in the use of the tool to ensure full understanding, the spectrum of ideas will be assessed; and the criteria for judging environmental relevance will be developed further.

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References

1. P. James, The sustainability circle: a new tool for product development and design. *Journal of Sustainable Product Design* **2** (1997), pp. 52–57.
2. **Brundtland, G H** *Our Common future* World Commission on Environment and Development, Oxford University Press, Oxford (1987).
3. **Philips Electronics** *From Green to Gold catalogue* Philips Corporate Environmental and Energy Office (CEEO), Eindhoven, The Netherlands (1998).
4. **Meinders, H** *Point of No return* Philips Ecodesign Guidelines Philips Corporate Environmental and Energy Office (CEEO), Eindhoven, The Netherlands (1999).
5. M. Charter, Editorial. *Journal of Sustainable Product Design* **8** (1999), p. 5.
6. **Brezet H** (Ed.) *PROMISE manual* Delft University of Technology, TME Institute and TNO product Centre, The Netherlands (1996).
7. **Fussler, C and James, P** *Driving Eco-innovation: a Breakthrough Discipline for Innovation and Sustainability* Pitman Publishing, London (1996).
8. **Cramer, J and Stevels, A** 'STRETCH: strategic environmental product planning with Philips sound and vision' *Journal of Environmental Quality Management*, Autum Issue (1997) 91–101.
9. M. Tassoul, Making sense with backcasting: the future perfect. *Journal of Creativity and Innovation Management* **7** 1 (1998), pp. 32–45.
10. **Osborn, A F** *Applied Imagination: Principles and Procedures of Creative Problem-Solving* Scribner's, New York (1963).
11. **De Bono, E** *Lateral Thinking: a Textbook of Creativity* Ward Lock Educational, London (1970).
12. **Gordon, W J J** *Synectics: the Development of Creative Capacity* Harper and Row, New York (1961).
13. **Lawson, B** *How Designers Think: the Design Process Demystified* 3rd ed., Butterworth Architecture, London (1997).
14. **De Bono, E** *Serious Creativity: Using the Power of Lateral Thinking to Create New Ideas* HarperCollinsBusiness, London (1992).
15. **Hanks, K** *Wake Up Your Creative Genius* Kaufmann, Los Altos, CA (1983).
16. **Buzan, T, and Buzan, B** *Mind Map Book* BBC Books, London (1995).
17. **Jones, E, Harrison, D and McLaren, J** 'The Product Ideas Tree: A tool for mapping creativity in Ecodesign' in *Proceedings of IDATER '99*, The Design Research Society, Loughborough, August 23–25 (1999).
18. C.M. Eckert, N. Cross and J.H. Johnson, Intelligent support for communication in design teams: garment shape specifications in the knitwear industry. *Design Studies* **21** 1 (2000), pp. 99–112.
19. N.A. Stanton and S. Stevenage, Learning to predict human error: issues of reliability, validity and acceptability. *Ergonomics* **41** 11 (1998), pp. 1737–1756.
20. C.L. Owen, Context for creativity. *Design Studies* **13** 3 (1992), pp. 216–228.
21. **Jones, E, Harrison, D and McLaren, J** 'Managing Creative Eco-innovation: Structuring Outputs from Eco-innovation Projects' *Journal of Sustainable Product Design* (in press).
22. J. Pritchard and N.A. Stanton, Testing Belbin's team role theory of effective groups. *Journal of Managerial Development* **18** 8 (1999), pp. 652–665.