The use of CASE to bridge the transition between primary and secondary school science in Ireland

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ABSTRACT This article describes how the Cognitive Acceleration through Science Education (CASE) programme was implemented in the final year of primary school and the first year of secondary school in a number of schools in Ireland. The original CASE programme, pioneered in the 1980s, proved successful in its aim to develop the science-reasoning abilities and achievement of 12- to 14-year-old pupils in the UK. The effectiveness of the programme, delivered in the primary–secondary school transition context, is reported in this article.

The difficulties surrounding the transition between primary and secondary school have been the focus of research for the past few decades in the UK, US, Australia, Finland and Ireland, amongst other countries. Difficulties have been cited in terms of pupils' progression from primary to secondary school in the form of non-curricular and curricular issues. There is evidence to show that for the majority of pupils, non-curricular problems are resolved relatively quickly (Garwood, 1986). However, the issues regarding the lack of academic progression appear to be less temporary, particularly in science (Braund, 2008). The literature identifies three main factors that may explain this phenomenon of regression and these are summarised as:

- repetition of work done at primary school, often with no added challenges, change in procedure or context;
- different teaching style, language and classroom environment between primary and secondary school;
- poor liaison between primary and secondary schools. Secondary teachers fail to make reference to pupils' previous learning experiences. Often a 'fresh start' approach is adopted that is not conducive to learning. In addition, often there is a deemed lack or trust regarding assessment levels from primary school.

In addition, it has been noted that pupils' motivation and interest decline in the early years of secondary school, as they see that work is repeated, and lessons underestimate what they are capable of and have already achieved (Galton, Gray and Rudduck, 1999). Given that these early years of secondary school are also the period of time when young people make decisions about subjects to pursue and career choice, it is vital that pupils are engaged in high-quality learning experiences (Speering and Rennie, 1996).

There has been no shortage of attempts to ease these issues regarding pupils' transition from primary to secondary school. Research in the 1990s showed that efforts were mainly in the administrative and social areas but more recent work has focused on addressing continuity/progression in the areas of curriculum and pedagogy. Driver *et al.* (1994) suggest that, although curricular continuity cannot guarantee progression, it does structure pupils' experiences and ideas in a way that helps move their conceptual understanding forward. Bridging units are one example of how this can be done. These are units/projects that enable year 7 secondary school teachers to gain insights into the ability and interest of year 6 pupils in their primary schools before transferring, typically at age 12, and to build on these as part of the work that continues into secondary school. By and large they are relatively short term and hosted in the time associated with the end of primary school and the start of secondary school.

The effectiveness of the Cognitive Acceleration through Science Education (CASE) programme as a bridging unit was explored in Ireland (McCormack, Finlayson and McCloughlin, 2014). CASE was selected as a suitable programme to implement as a bridging unit for two reasons. Firstly, with regard to the age range suitability, the programme was originally designed for implementation with 11- to 14-year-old pupils and this range coincides with the age when pupils in Ireland complete primary school and start secondary school. Secondly, the programme was designed for implementation over a two-year period and this fitted with the two years associated with the primary–secondary transition.

Moreover, the rationale for CASE explains its philosophy and further reasons for its suitability. Research from the 1970s had shown that success in secondary school science and mathematics requires a high level of processing, often called formal operational thought (Shayer, 1970). This term, coined by Inhelder and Piaget (1958), refers to cognitive structures that include a set of reasoning patterns. The main reasoning patterns are grouped as shown in Figure 1. However, the results of the *Concepts in Secondary Mathematics and Science* (CSMS) survey showed that by the age of 14 years only just over 20% of the pupils in the representative British population were at the early formal operational stage (Shayer and Adey, 1981). The remainder of the sample were at lower levels of cognitive ability. This highlighted that there was a mismatch between the pupils' thinking abilities and the demands made by the secondary science and mathematics curricula. The CASE programme, pioneered in the early 1980s by Philip Adey, Michael Shayer and Carolyn Yates at King's College London, was designed as a two-year intervention with the aim of increasing the proportion of secondary pupils capable of formal operational thinking. The materials of CASE were called *Thinking Science* and they were first published in 1989.

The theoretical foundation of CASE is partly Piagetian and partly Vygotskian. Within the lessons there is an emphasis on providing situations of cognitive conflict that encourage equilibration and the construction of the reasoning patterns of formal operations. There is also an emphasis on social construction of reasoning, through metacognitive reflection and carefully managed use of the language of thinking. In particular, the authors were influenced by Vygotsky's Zone of Proximal Development (ZPD), which proposes that children not only have a set of developed skills but also have some undeveloped cognitive skills, which they are capable of using successfully with the mediation of a peer or an adult.

This philosophy is underpinned in

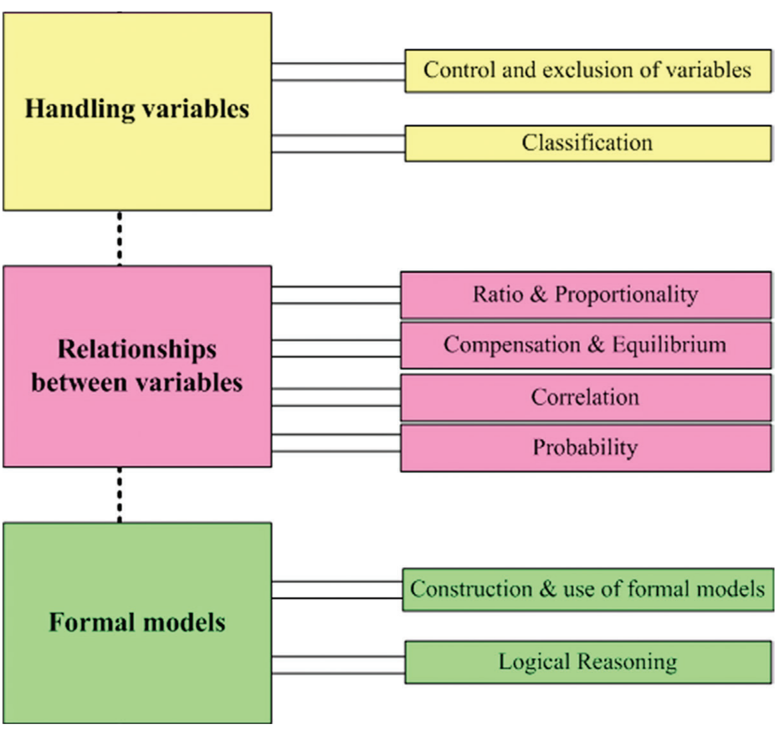

Figure 1 Schemata of formal operations

the five 'pillars' of CASE namely, concrete preparation, cognitive conflict, social construction, metacognition and bridging. Concrete preparation is where the context of the lesson is set. Familiarity is established with vocabulary and apparatus, and the pupils are presented with an opportunity to become acquainted with terminology. This is so that difficulties encountered in the lesson are cognitive ones, and not due to misunderstandings regarding vocabulary or equipment to be used during the lesson. Cognitive conflict is a term used to describe a dissonance that happens when pupils are faced with an event that they cannot explain using their current conceptual framework or method of processing data (Adey, 1992). Where cognitive conflict has disturbed the pupil's equilibrium or feeling of understanding, construction is the process that follows. This is the process where equilibrium is re-established through the development of a more powerful and effective way of thinking about the problem. The overall aim of the construction zone in the lesson is to maximise the opportunity that each pupil has for constructing their reasoning patterns, which he/she will rely on for more powerful thinking in the future.

Effective CASE lessons include a great deal of on-task discussion and constructive argument in small groups and between groups. Metacognition put simply means thinking about one's own thinking. An important part of the process of developing thinking skills is for pupils to become conscious of and articulate the thinking they employ to solve different problems. Thinking back and reflecting aloud helps to develop this consciousness. The requirement for consciousness means that it is a process that best takes place after a thinking act, since at the time pupils are engaging in a problem-solving activity, their consciousness must be devoted to that. Only afterwards can they think back to the steps they took, and become aware of how their own conceptualisation changed during the activity. Bridging, the final pillar in the CASE methodology, is the explicit link in the chain of developing, abstracting and generalising reasoning into other contexts.

Results of other CASE programmes

The CASE programme has an impressive reputation in the field of enhancing pupils' cognitive development, with numerous UK and international studies highlighting the beneficial effects on pupils' cognitive development (Adey, 1992; Shayer and Adey, 1993; Adey and Shayer, 1994), as well as academic achievement in other curriculum subjects such as English and mathematics (Shayer, 1999).

The rationale for implementing the programme across the primary–secondary school transition in Ireland was as follows:

- some primary and secondary school pupils will be taught science through the CASE methodology for two years, across their primary and secondary school transition;
- the effects of CASE can be investigated in terms of its impact on pupils' cognitive development across the two years and two phases;
- primary and secondary school teachers will receive professional development in the CASE methodology.

The design of the study

Six secondary schools were identified and invited to be part of the study. As one of the main aims was to examine the effects of implementing CASE across the primary and secondary school, the selection of the feeder primary schools to be involved was important. This selection process involved obtaining information from secondary schools about their main feeder schools. From this, eleven primary schools were selected. Intervention and non-intervention groups (groups that did not receive the CASE intervention) were identified in each primary and secondary school. Figure 2 shows the arrangement, with the number in the circles indicating the number of pupils who were tracked in the study.

Adaptations of CASE for Ireland and teacher development

The original CASE programme consisted of 32 lessons. For this study the lessons were mainly divided for use either at primary school or at secondary school. Table 1 shows all 32 lessons that were selected to be part of the intervention and at what phase they were taught over the two years. *Thinking Science 1* was the name given to the programme at primary level and *Thinking Science 2* to that at secondary level.

Each *Thinking Science* lesson was designed to address each of the reasoning patterns of formal operational thought outlined in Figure 1. Each reasoning pattern was addressed through a series of lessons but the authors of *Thinking Science* did not envisage that each would be developed independently of the entire construction of formal operations. The sequence of these reasoning patterns and their frequency is shown in Figures 3 and 4.

It was essential, and central to the rationale for the study, that the pupils who received the intervention in the primary school did not repeat the same lessons in their secondary school, as

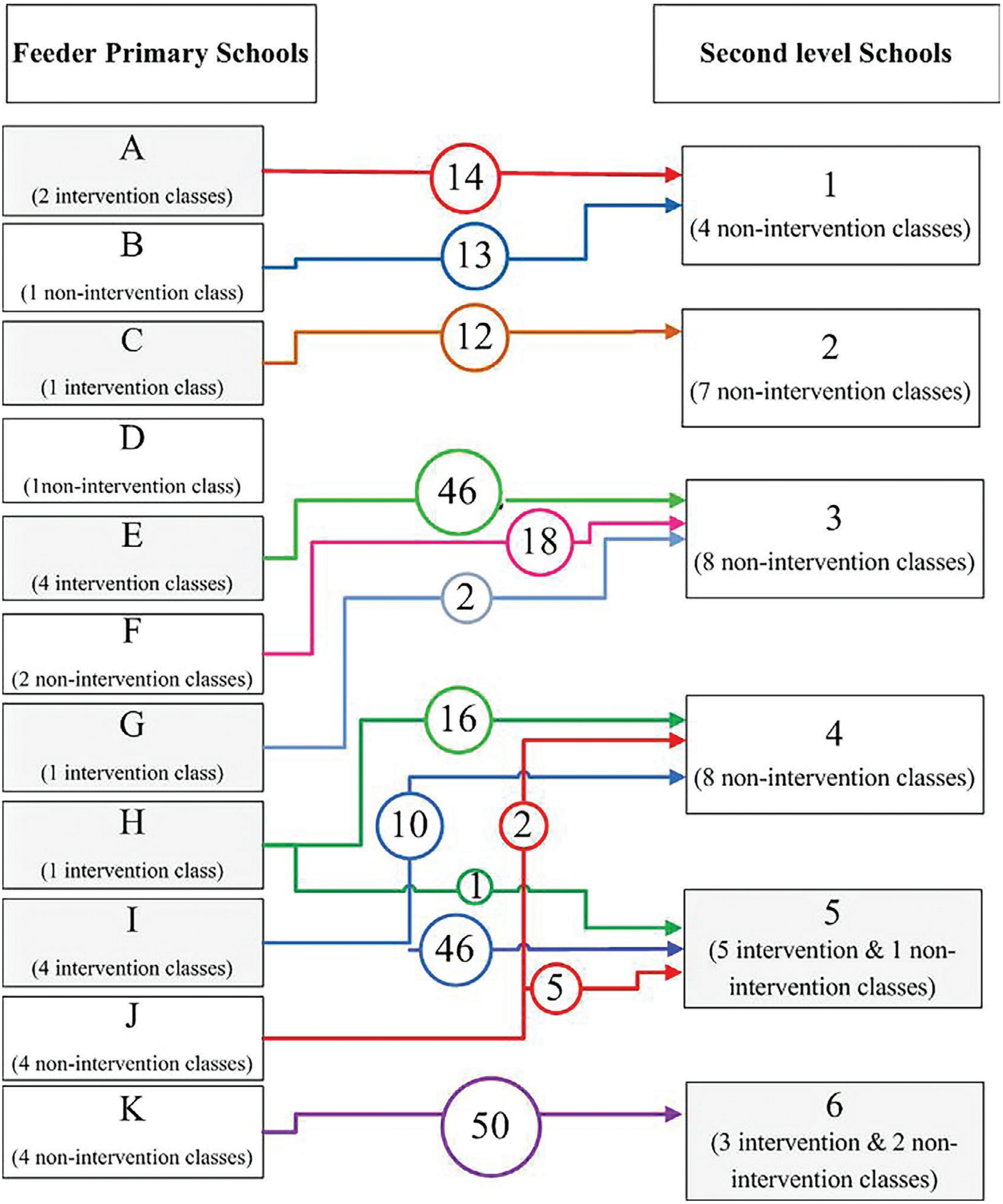

Figure 2 Map of cross-phase transfer across primary and secondary level schools and number of pupils tracked

Table 1 List of *Thinking Science* lessons and the phase they were taught in

Lesson number	Lesson name	Taught in Primary	Taught in Secondary
1	What varies?	✓	✓
2	Two variables	✓	✓
3	The fair test	✓	✓
4	What sort of relationship?	✓	✓
5	Roller ball	✓	
6	Gears and ratios	✓	
7	Scaling: pictures and microscopes	✓	✓
7a	Bean growth 1	✓	
7b	Bean growth 2	✓	
8	The wheelbarrow	✓	
9	Trunks and twigs		
10	The balance beam		✓
11	Current, length and thickness		✓
12	Voltage, amps and watts		✓
13	Spinning coins	✓	
14	Combinations		
15	Tea tasting	✓	
16	Interaction	✓	✓
17	The behaviour of woodlice	✓	
18	Treatments and effects	✓	
19	Sampling: fish in a pond	✓	
20	Throwing dice	✓	
21	Making groups		✓
22	More classifying birds		✓
23	Explaining states of matter		✓
24	Explaining solutions		✓
25	Explaining chemical reactions		✓
26	Pressure		✓
27	Floating and sinking	✓	✓
28	Up hill and down dale		✓
29	Equilibrium in the balance		✓
30	Divers		✓

this would be of little value, as well as being repetitive for them. The exception was in the case of the first four lessons where the concepts of variables and fair testing were addressed explicitly. As most of the subsequent lessons required reference to variables, developed in these four lessons, it was decided that these four needed to be taught in secondary school to give the pupils who had not received the intervention at primary school a good foundation in the reasoning patterns. Three other lessons were included in both phases.

The order and selection of lessons was a key feature. As with the original *Thinking Science* programme, the lessons used in this study were arranged in a hierarchical manner in terms of their cognitive demand and in sequence with the reasoning pattern identified. For continuity, a collection of three or more lessons with the same reasoning pattern together. For example, all of the lessons on the reasoning pattern 'proportionality' (Lessons 6, 7, 8) were placed in *Thinking Science 1*, the programme implemented at primary school level. The charts of the estimated operating

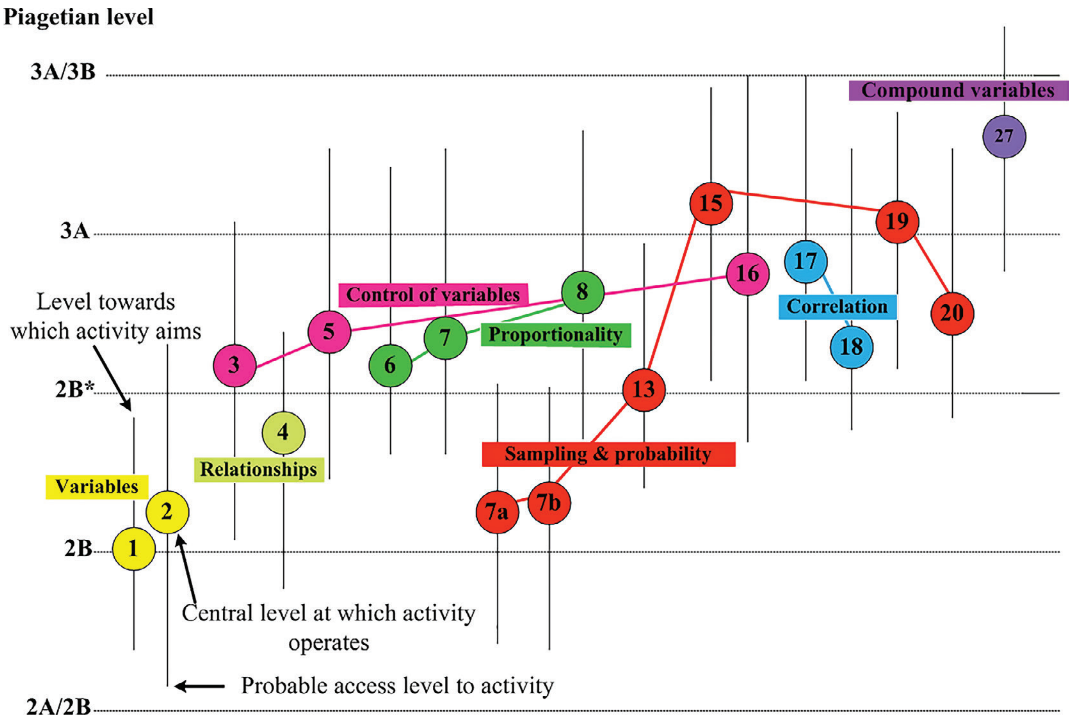

Figure 3 Map of *Thinking Science 1* lessons and estimated operating range (including the reasoning pattern indicated in colour)

range for the lessons in each phase are shown in Figures 3 and 4. The numbers of each lesson can be matched to Table 1. The main Piagetian level required for the lesson is shown on the left-hand side of each of the figures, e.g. 2A/2B denotes mid-concrete, 2B denotes late concrete, 2B* denotes concrete generalisation, 3A denotes early formal and 3A/3B denotes mid-formal. The sequence of each of the lessons is indicated by their position on the chart from left to right.

The original *Thinking Science* programme was designed for use in secondary schools in the UK and the lessons were designed to be taught by specialist science teachers. One of the main differences between primary and secondary schools is the previous education and training of teachers in the area of science. Many primary school teachers have not studied science since their own secondary level education and this can lead to lack of confidence regarding teaching science. As the study involved the lessons taught in primary school, it was deemed necessary to provide primary school teachers with some content knowledge of the concepts covered in each lesson. This served two purposes: firstly, it cut down on extra time that may have been spent by teachers researching the content; secondly, it helped to instil confidence in the teachers and make them feel more adequately prepared for the lessons.

The professional development programme comprised initial training sessions, followed by three focused workshops throughout the time of the study. In addition, teachers were offered the opportunity to team-teach the lessons in order to build their confidence and expertise.

Summary of results

Pupils' cognitive levels, in both the intervention and non-intervention groups, were analysed using tests of cognitive development. These were the Science Reasoning Tasks (SRTs) (NFER, 1979) developed by the CSMS team. These tests were also used to test the effectiveness of the original CASE materials in the UK study.

Prior to the start of the programme, pupils were tested using Science Reasoning Task 1, administered as a base-line test. The results from

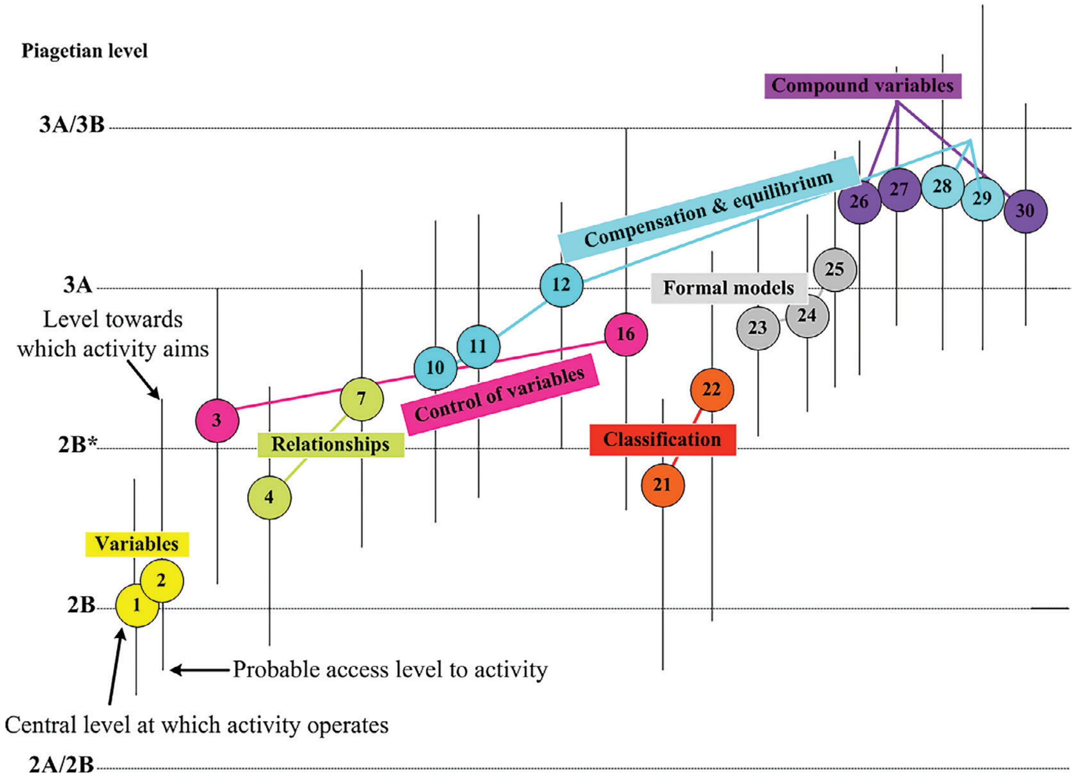

Figure 4 Map of *Thinking Science 2* lessons and estimated operating range (including the reasoning pattern indicated in colour)

this showed that there was no significant difference between the intervention and non-intervention group. There was a significant difference in the results of the post-test, Science Reasoning Task 4, between both groups, where the mean of the intervention group (mean = 5.27) was higher than that of the comparable non-intervention group (mean = 3.38). The effect size of the programme was 1.06σ, corresponding to a large effect size, according to Cohen (1988). This finding was also comparable to that found in the original CASE research (Shayer and Adey, 1993).

The primary and secondary school teachers who were involved in the study all reported very positively about their experience of using the programme. Some quotations from interviews conducted at the end of the programme are included:

My overall impression of the programme is very positive. There is no doubt that children's power of reasoning developed. (primary school teacher, School G)

The reasoning developed was positive for maths, English comprehension and even history. (primary school teacher, School G)

Students responded well, some found it heavy going as we were teasing out at a more intense level than students are used to. (secondary school teacher, School 5)

Conclusion

It was evident from the empirical evidence and the views of teachers that the *Thinking Science 1* and *2* programmes were beneficial to pupils' cognitive development across both phases. Beyond this, the programmes were successfully implemented as 'bridging units'. This study also highlighted the benefits for teachers across both phases in engaging in professional development and contributing to a community of practice.

Since this study concluded there has been further research conducted on the effects and features of CASE in the primary and secondary school setting (Ryan, 2014; Oliver, Venville and Adey, 2012; Oliver and Venville, 2016). In addition, the Education Endowment Foundation funded a randomised control trail of 53 UK secondary schools to assess the effects of *Let's Think Secondary Science*, a programme based on the original CASE materials. The results are due to be published later in 2016.

Anecdotal evidence from primary and secondary school teachers suggests that there is a keen interest in the philosophy of CASE and its potential to influence cognitive development, but allocating time with the existing demands of the curriculum at both primary and secondary school is the limiting factor. However, the results from the multitude of studies indicate that time spent implementing CASE is time well spent.

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