

International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

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Published online: 15 Jul 2014.

To cite this article: Lorraine McCormack, Odilla E. Finlayson & Thomas J.J. McCloughlin (2014) The CASE Programme Implemented Across the Primary and Secondary School Transition in Ireland, International Journal of Science Education, 36:17, 2892-2917, DOI: 10.1080/09500693.2014.938711

To link to this article: http://dx.doi.org/10.1080/09500693.2014.938711

*International Journal of Science Education*, 2014
Vol. 36, No. 17, 2892–2917, http://dx.doi.org/10.1080/09500693.2014.938711



# The CASE Programme Implemented Across the Primary and Secondary School Transition in Ireland

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In the Irish education system, there is little continuity between the primary and secondary education systems. The transfer between these systems is particularly problematic in the area of science. In order to alleviate some of these problems, as well as to enhance the cognitive development of students, the Cognitive Acceleration through Science Education programme was adapted for use and implemented across the primary–secondary school transition in Ireland. The programme was delivered in a variety of ways across the two levels, including the teacher and researcher teaching the programmes individually and team-teaching arrangements. The results on cognitive development measures showed that the students who were taught the programme in primary and secondary school made significant gains, when compared to the non-intervention group. There were also gains evident for students who only received one part of the programme (i.e. in either primary or secondary school). The greater gains, in terms of effect size, were evident at secondary school. The rationale, methodology and results are detailed in this paper.

Keywords: *Cognitive acceleration; Primary school; Secondary school; Higher-order thinking; Longitudinal study; Quantitative research*

## Background

In Ireland, there is very little articulated pedagogical continuity between primary and secondary schools, both in practice and theory. There is much research published

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regarding the transitions from primary to secondary school (Anderson, Jacobs, Schramm, & Splittgerber, 2000; Braund, 2002; Huggins & Knight, 1997). Problems emerge in terms of students' progression from primary to secondary school through non-curricular and curricular issues. There is evidence to show that students' non-curricular problems are not long-lived and in adequate time they quickly integrate into secondary school (Garwood, 1986). However, regarding academic progression, the issues are less temporary, particularly in science. An evidence shows that nearly one-third of students fail to make the expected grade (predicted from performance at the end of Key Stage 2 (age 11 years)) in science tests at the end of Key Stage 3 (age 14 years) (Braund, 2008). The regression is not as severe for English and Mathematics. In addition, the levels of engagement also fell more in science. After transfer the number of pupils 'fully engaged' fell by 26% in Science, compared to 5% in English and 12% in Maths (Galton, Gray, & Ruddock, 1999).

A report carried out by Smyth, McCoy, and Darmody (2004) on academic transfer found that the majority of Irish secondary-school students did not show any improvement on test scores on reading and mathematical computation over the course of the first year. Studies highlighting the differences between subjects taught and teaching methodologies used in the Irish primary and secondary schools show that a substantial number of students experienced discontinuity in learning experiences between both levels (Smyth et al. 2004). A significant proportion of post-transfer students surveyed did not see the secondary-school curriculum as following on naturally from that at primary school, and also the majority view the teaching methods as being quite different.

There are many theories put forward to explain the reasons for post-transfer regression, and they fall into four main categories. Firstly, the students repeat work done at primary school, often with no added challenge, change in procedure or context (Barber, & Mitchell, 1987; Galton et al., 1999). Jarman (1998) reported, in an extensive study on the school population of Northern Ireland, that students claimed that much of science done in primary school was repeated when they entered secondary school. In contrast, the teaching style and language, as well as classroom environment were very different in secondary schoolcompared to primary school and students often find it difficult adapting to this change in learning culture (Hargreaves & Galton, 2002; Pointon, 2000). Galton and Willcocks (1983) found that the whole class teaching accounted for twice as much time at secondary school compared to that in primary school. Another potential factor in this issue is that secondary-school teachers fail to make reference to students' previous learning experiences. In addition, the transferred information on students' previous attainments is rarely used to plan curriculum experiences (Doyle & Hetherington, 2005; Nicholls & Gardner, 1999). An Irish study (Eivers, Shiel, & Cheevers, 2006) questioned secondary-school science teachers on their familiarity with the current primary-school science curriculum, and the findings indicated limited teachers' knowledge, with less than 6% of teachers being familiar with the science content or processes of the curriculum. Fifty-eight per cent were unfamiliar with the science content, with 69% reported to be unfamiliar with the science processes in the primary-school science curriculum. Another reason for this post-transfer regression is that secondary-school teachers distrust the levels that their students have been assessed at in primary schools (Schagen & Kerr, 1999). This reason may be used to justify the 'start from scratch' attitude of teachers when planning learning experiences for students (Nott & Wellington, 1999). These problems are not unique to the UK and Irish system, with similar problems been reported in studies from USA (Anderson et al., 2000), Australia (Pietarinen, 1990) and Finland (Pietarinen, 2000) also.

Science at primary school in Ireland is a relatively new development, having been re-introduced as part of the Social, Environment and Scientific Education curriculum in 2003. This development, however, has not been without complications. Anecdotal evidence suggests that many primary-school teachers feel inadequately prepared to teach science. The 2002 Task Force on Physical Science report shows that only a minority of primary teachers took a physical science subject to upper secondary school (NCCA, 2007). Although this is not a requirement for entry to initial teacher education at the primary level, it may be reflective of teachers' lack of confidence in the area. Major concerns have also been reported about insufficient priority and time given to address fully both pedagogy and content related to science in pre-service teacher education (Task Force on the Physical Sciences, 2002). Another repercussion of the re-introduction of science appears when the students transfer into secondary school and become bored by the repetition that they experience in science. The difficulty for the secondary-school teacher is motivating students that have done science before and teaching those that have not.

Another issue that is evident at secondary school science is the perceived difficulty of studying science. International research shows that Irish students are not unique when it comes to finding science difficult. The results from the Relevance of Science Education report (Matthews, 2007) showed that about 50% of students regard Junior Certificate science as a demanding and difficult subject. This issue has implications regarding the up-take of science at upper secondary- and tertiary-level education. Participation in physics and chemistry at upper secondary school is relatively low, 20% and 17%, respectively. A study in the UK identified that students' perception of science as a difficult subject is a major factor in their subject choice (Havard, 1996).

The research on the cognitive development of students indicates that there is a broad range of cognitive abilities on entry into secondary school, ranging from the average 6-year-old to the above average 16-year-old (Shayer, Kucheman, & Wylam, 1976; Shayer & Wylam, 1978). The results from the Concepts in Secondary Mathematics and Science (CSMS) survey showed that the majority of young people were operating only at the concrete levels, with only 30% of students at the ages of 14/15 years demonstrating formal operational thinking. More recent research has determined that the proportions at the formal operational levels have decreased (Shayer, Ginsburg, & Coe, 2007). This profile is also evident in Botswana (Prophet & Vlaardingerbroek, 2003) and Turkey (Cepni, Ozsevgec, & Ceerah, 2004; Çepni, Özsevgeç, & Gökdere, 2003). Adey (1999) suggests that the worldwide difficulty of science concepts tended to be masked by rote learning.

Inhelder and Piaget (1958) proposed that adolescence is the time of development from concrete to formal operational thinking. During concrete operations, between the ages of 7 and 11 years, the child's reasoning processes become logical. As the term 'concrete' suggests, the child's thinking in this stage is based on their experiences of real or concrete objects or events. The limitations of this period include the solving of hypothetical problems, problems that are entirely verbal and some problems that require complex operations. Attainment of the formal operational period usually means the child is in better position to be able to organise data, reason scientifically and generate hypotheses. The problems which were deemed impossible to solve at the concrete operational stage such as those involving combinatorial thought, complex verbal problems, hypothetical problems, proportions and conservation of movement are now possible at the formal operational stage.

In response to the findings from the CSMS survey, which highlighted the mismatch between the student population's cognitive abilities and the demands of the science curricula, the Cognitive Acceleration through Science Education (CASE) programme was developed. CASE was designed as an intervention in the science curriculum for 11–14-year-olds with the ultimate aim to increase the proportion of secondary-school students capable of formal operational thinking. The CASE materials were published and known as Thinking Science (Adey, Shayer, & Yates, 1989). There are 32 lessons in the original materials and they were designed to be delivered over a period of two years, at a rate of one lesson every two weeks. The concepts of the lessons are directly derived from Piaget's schemata of formal operational thinking. These include control and exclusion of variables, proportionality and ratio, compensation and equilibrium, classification, correlation and probability and formal models.

There is a considerable bank of evidence supporting the positive effects of CASE on students' cognitive development (Adey & Shayer, 1993, 1994; Shayer, 1999). The results from cognitive tests on CASE experimental groups (over 2000 students in 11 British schools) when compared with national data obtained from CSMS survey showed that the proportion of students using higher order thinking was significantly greater than the national average, in the order of 0.67–1.26 standard deviations. There is also evidence to show gains in scholastic achievement in science, mathematics and English (Adey & Shayer, 1994; Shayer, 1999). Two years after the completion of the intervention, students who had been taught through CASE achieved higher results than peers in the national examination taken, General Certificate of Secondary Education. The average gains were in the order of 0.6 standard deviations in science, 0.5 standard deviations in mathematics and 0.57 standard deviations in English (Adey & Shayer, 2002).

The effectiveness of CASE has been reported in other countries also, including Australia (Endler & Bond, 2001), USA (Endler & Bond, 2007), Pakistan (Iqbal & Shayer, 2000), Finland (Hautamäki, Kuusela, & Wikström, 2002) and Malawi (Mbano, 2003).

## Design of This Study

### *Research Questions*

The purpose of this research was to determine the effectiveness of the CASE programme when implemented across two levels of the Irish education system, in terms of students' cognitive development.

The research questions reported in this paper are:

(1) What is the effect of CASE on students' cognitive development when implemented across the primary–secondary school transition?
(2) What is the effect of CASE on students' cognitive development when students participate in either the first year of the programme (at primary school) or the second year of the programme (at secondary school)?

The CASE programme was chosen as a very suitable method for this study for several reasons, including its impressive reputation with regard to the enhancement of cognitive developmental levels. These are:

(1) Due to its age range suitability
In the Irish system, students attend primary school typically up to the age of 12 years, after which they transfer to secondary school, approximately one year after the cohort in the UK. The CASE programme was initially designed for the use in the Year 7 and 8 classes, with students approximately aged 12 and 13 years. For this reason, it was appropriate to use CASE in the final year of primary school and the first year of secondary school in Ireland.
(2) Length of the programme
As mentioned previously, CASE was designed as an intervention to be implemented over two years. Adey and Shayer believed that in order for any intervention to have any tangible effects on students' cognitive development, the intervention would have to last for long periods of time (i.e. two years). This timeframe suited the application across the final year of primary and first year of secondary school.
(3) Context specificity
CASE was also suitable for use as it was set in the context of science. Science is one of the areas noted in literature that is most affected by the transition from primary to secondary school. In addition, issues at primary school with regard to the teaching of science implied that there was a 'need' for some form of support/development in schools. It was also hoped that the investment in training, time and resources would be reaped further down the line.

### *Research Design and Sample*

A quasi-experimental design with intervention (experimental) and non-intervention (control) groups was set up to address the research questions. The study included the collection of quantitative data, in the form of pre- and post-tests of cognitive development.

Initially, a semi-random convenient sample of six secondary schools was chosen to include single sex and co-educational schools as well as schools that had compulsory and non-compulsory science. As one of the main aims of the study was to examine the effects of implementing the CASE intervention across the primary and secondary schools, the selection of the feeder primary schools to be involved was important. It was important to have a large enough cohort of students to follow through for effective analysis to be possible. This selection process involved gathering anecdotal evidence from secondary schools about their main feeder schools. From this, 11 primary schools were selected to be part of the study and they included single sex and co-educational schools. Figure 1 demonstrates the design of the study and the sample number in each of the intervention and non-intervention groups at primary and secondary schools. Figure 1 also shows the number of students that transferred from the intervention and non-intervention groups across the primary and secondary schools.

Figure 2 shows the map of the cross-transfer methodology and the number of students tracked across the levels, as well as the number of intervention and non-intervention classes in each primary and secondary school part of the study.

## Methodology

### *Underpinning Philosophy of CASE*

The theoretical foundation of the CASE method is partly Piagetian, with an emphasis on providing conflict situations which encourage equilibration and the construction of the reasoning patterns of formal operations by students themselves. Of equal importance is the Vygotskyian influence, with an emphasis on social construction of reasoning, through metacognitive reflection and carefully managed use of the language of thinking. In particular, they were influenced by his proposal of a Zone of Proximal

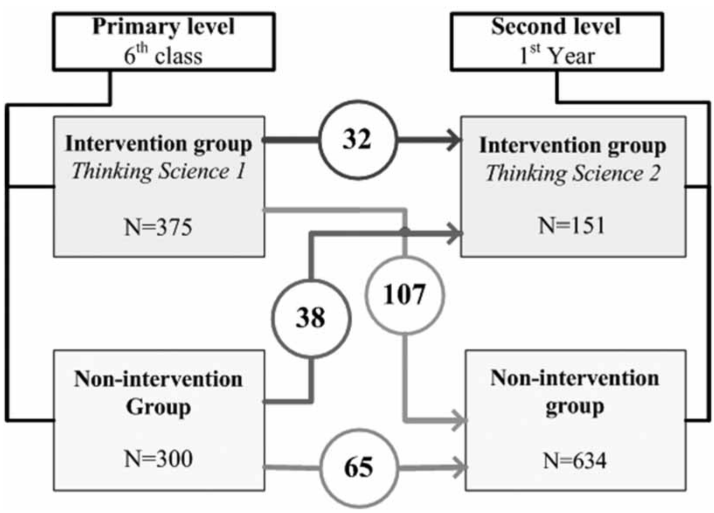


Figure 1. Sample of students in cross-phase transfer

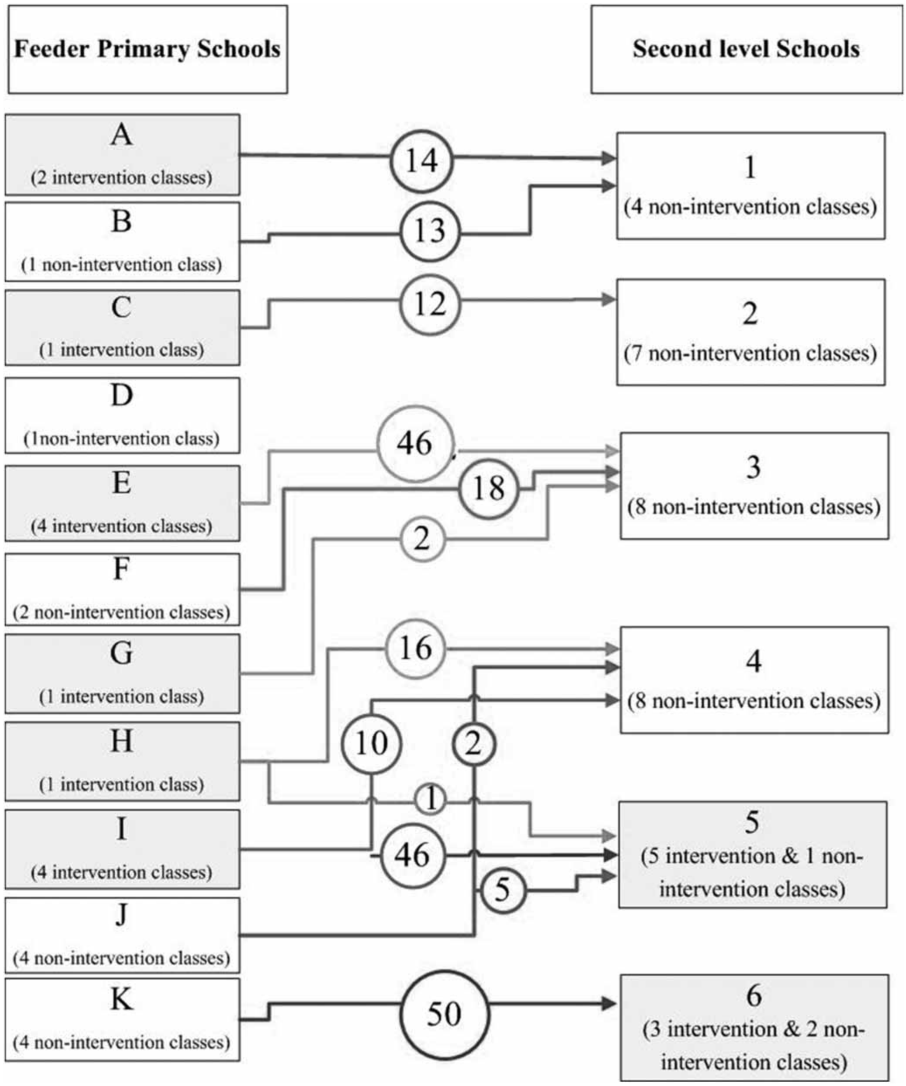


Figure 2. Map of cross-phase transfer across primary and secondary schools and number of students tracked

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 effort of the child or due to the mediation of a peer or an adult. Several aspects of the CASE strategy have potential to facilitate students' growth within Vygotsky's ZPD. The developers were also strongly influenced by the Instrumental Enrichment programme (Feuerstein, Rand, Hoffman, & Miller, 1980); in particular, the idea of bridging where a term or concept learned in one context is applied in a different but relevant area. This philosophy is underpinned in the five 'pillars' of CASE, which are (1) concrete preparation, (2) cognitive conflict, (3) social construction, (4) metacognition and (5) bridging.

Concrete preparation is a part of the lesson where the context of the lesson is set. Familiarity is established with vocabulary and apparatus, and the students are presented with an opportunity to become acquainted with terminology. In essence, the purpose of concrete preparation in the lesson is to ensure that any difficulties encountered in the lesson are purely intellectual and not due to misunderstandings regarding vocabulary or equipment used during the lesson. Central to the process of cognitive acceleration is the idea of setting problems which students cannot readily solve, using their present level of thinking. The pillar that addresses this is cognitive conflict. Cognitive conflict is a term used to describe a dissonance which happens when a child is faced with an event that he/she cannot explain using their current conceptual framework or method of processing data (Adey, 1992). The goal of the CASE intervention lessons is to ultimately induce higher order thinking. The cognitive conflict scenarios provided should be such as to help students construct these higher order or formal operational reasoning patterns for themselves and not merely to engage in scenarios where cognitive conflict arises concerning a particular topic, and the aim of the activity is the construction of the concept. Where cognitive conflict has disturbed the student's equilibrium or feeling of understanding, construction is the process which 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 student has for constructing their reasoning patterns, i.e. schemata, which he/she will rely on for more powerful thinking in the future. Effective cognitive acceleration lessons include a great deal of on-task discussion and constructive argument in small groups and between groups. Metacognition simply means thinking about one's own thinking. An important part of the process of developing thinking skills is for students to become conscious of and articulate about 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 must take place after a thinking act since at the time a student is 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 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. Bridging takes place when teachers transfer class management strategies that characterise cognitive acceleration lessons, to the rest of their teaching.

### *Adaptation of CASE for Cross-Phase Study*

In this study, the CASE programme was adapted for use across two phases of the education system in Ireland, namely the final year of primary school and the first year of secondary school. The Thinking Science materials were divided into two programmes. Thinking Science 1 was the part of the programme adapted for the primary school and Thinking Science 2 was the part of the programme adapted for use in the first year of secondary school.

### *Adaptation for Primary School*

The aim of the Thinking Science 1 programme was to encourage cognitive development, in the context of science, in the final year of primary school. In order for the CASE programme to be used successfully at primary school in Ireland, the materials need to be prepared for use with non-specialised science teachers.

One of the main differences between primary and secondary school is the previous education and training of teachers in science. Many primary school teachers have not studied science since their school days and yet their duty is to teach this subject in an informative and exploratory manner. The original CASE materials provided teachers with a Teacher's Guide complete with an introduction, apparatus summary, procedure summary and a detailed lesson plan. The introduction provided information on the main purpose of the lesson and the main points of the lesson. There was a lack of background on the scientific detail in the original materials, as they were designed for specialised science teachers at secondary school. For Thinking Science 1, it was deemed necessary to provide the teachers with some content knowledge on the area covered in each Thinking Science 1 lesson. This served two purposes, firstly it cut down on extra time that may have been spent by teachers sourcing information and researching additional material on the content and secondly to instil confidence in the teachers and make them feel more adequately prepared for the lesson. It is reasonable to suggest that a lesson is more likely to run smoothly and be of more value to students if the teacher is confident and well-briefed on the content. This is particularly true of the CASE material. The essence of any CASE lesson is the underlying reasoning patterns and the cognitive conflict induced on students and the re-construction of their way of thinking to accommodate new evidence. If the teacher is unsure of the content in which this is set, their scope for scaffolding this cognitive conflict is grossly limited. However, it was unrealistic to think that by providing more background material to a teaching resource these aims could be achieved. The clarification of concepts and areas of confusion, as well as more detailed explanations, was provided in the teacher training. This was a more ideal setting as each teacher's misconceptions was addressed and they had the opportunity to seek clarification on information that did not necessarily make sense for them in text.

### *Adaptation for Secondary School*

When the secondary-school teachers in the intervention schools were approached about teaching the Thinking Science 2 programme, their commitment very much relied on the connectivity of the CASE programme to the aims and objectives of the Junior Certificate science curriculum. According to teachers' opinions, the Junior Certificate science curriculum is very packed, with little time allocated for addressing topics not featured in the curriculum. The Department of Education recommends between 240 and 270 hours of class contact time over three years (equivalent to four class periods a week) in the junior cycle, in order to achieve the aims, objectives and learning outcomes of the science syllabus (NCCA, 2003). However, anecdotal evidence showed that in the schools that participated in this study, the majority allocated on average only three 40-minute classes per week for first-year science. In order to encourage the participation, and in the hope of the long-term use of the CASE programme, it was necessary to make the lessons as applicable to the curriculum as much as possible. Adey, Shayer, and Yates (2001) recommend that the Thinking Science lessons are kept separate from the content curriculum and they are referred to as 'something special', 'a Thinking Science lesson' or 'brain training'. However desirable that this may be, it was not possible within the constraints of the Junior Certificate science programme or even as a separate subject on the timetable. Due to these restrictions it was decided to relate the content of the CASE lessons as much as possible to the curriculum objectives, without altering the context of the lessons. Each activity was matched with its corresponding aim on the Junior Certificate science curriculum. In addition, the lessons were ordered in accordance with Thinking Science—3rd edition—(Adey et al., 2001) in order to comply with the spiral 'staircase' of development of the programme. The teachers were encouraged to sequence their scheme of work around the Thinking Science 2 programme as much as possible.

The Irish lower secondary science curriculum (NCCA, 2007) comprised 30 mandatory student activities—10 each from biology, chemistry and physics—that are envisaged to be completed over the course of the three-year programme. It is recommended that the activities are conducted in small groups of students and each student is required to complete reports on these activities, for assessment purposes. All of the secondary school teachers involved in the study had planned to do 10 of the mandatory experiments in each of the three respective years. In order to accommodate the intervention schools' participation, the content of a selection of these mandatory experiments was integrated into the Thinking Science 2 programme. The lessons required little change but the commitment from the teachers to embark on the new methodology while implementing this component was necessary.

Unlike in the primary schools, where time was more flexible, at secondary school the Thinking Science 2 lessons had to be implemented within set class periods. In order to accommodate this often the bridging exercises/worksheets had to be scaled down or given as homework. Coming back to this exercise in the next science class was not ideal for the optimum effectiveness of the activity, but where there was little choice this had to be done. A selection of the lessons were more suitable for shorter class periods, i.e. 40 minutes. Overall, a double class was required to complete the Thinking Science 2 lessons in full.

Currently, 4% of secondary schools in Ireland have laboratory technicians employed. This is in stark contrast with Northern Ireland and the UK, where all secondary schools employ technicians (Lawless, 2009). In Ireland, the technical preparations and issues are dealt with by the teachers. In every Thinking Science 2 lesson, some amount of technical preparation was necessary, albeit to varying degrees. For example, Lesson

10 'The balance beam' requires the manufacture of a class set of wooden laths with specially drilled holes, while Lesson 22 'More classifying birds' requires the photocopying of sets of work cards and individual worksheets. To ensure that teachers were not troubled with this technical preparation, each intervention class was provided with the full range of materials (equipment, chemicals, etc.) and worksheets needed for each of the Thinking Science 2 lessons. Any preparation that the teacher had to do for the class was solely on the delivery of the cognitive acceleration lesson.

### *Selection of Material*

The order and selection of lessons was one of the key features that was taken into account in the adaptation of the materials, to make them suitable for use in the Irish primary and secondary-school classrooms.

As with the original Thinking Science materials, the lessons used in this study were arranged in a hierarchical manner. The authors give a word of warning regarding the random selection of activities to suit a purpose in a class and also about tampering with the order of the activities (Adey et al., 2001). The objectives of the lessons relate to the development of general reasoning patterns (i.e. proportionality), and if the activities themselves are chosen at random to suit a need their benefits will be fruitless and the main aim of enhancing cognitive development will be lost. This presented a logistical challenge in this study as the programme was implemented across two years, across two different systems. Upon analysis of the science curricula at both levels and deliberation with teachers, it was clear that there was varying degrees of freedom within the two systems. Compliance with the recommendations of the authors to keep the Thinking Science lessons separate from curriculum content was feasible for primary school, but less so at secondary school. Figures 3 and 4 show the order of the lessons at primary and secondary school, and their operating range. The main Piagetian level required for the lesson is shown on the left hand side of each of the figures, with the sequence of each of the lessons being indicated by their position on the chart from left to right. The lesson names and the programme that they featured in this study is shown in Table 1.

It was deemed preferable, and central to the methodology that the students who received the intervention in primary did not repeat the same lessons, as 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 in an explicit manner. As most of the lessons require reference to the notion of variables, developed in these four lessons, it was decided that they need to be repeated in Thinking Science 2 to give the students who had not received the intervention at primary school a good foundation in the schema.

### *Teacher Training*

Research on teacher professional development suggests that changing teacher pedagogy cannot be done through short, one-off courses (Joyce & Showers, 2002;

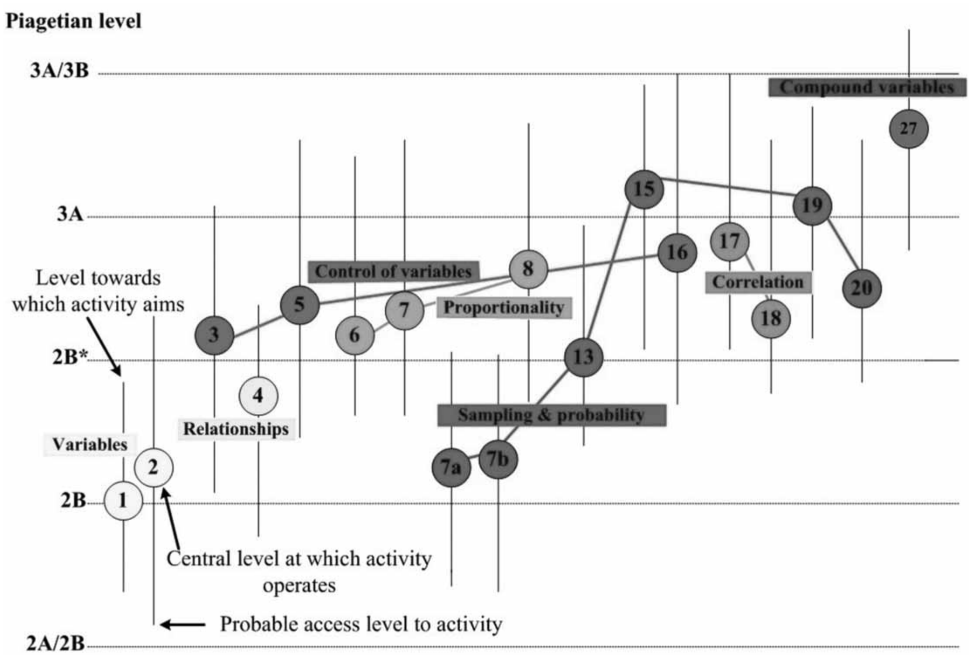


Figure 3. Map of Thinking Science 1 lessons and estimated operating range

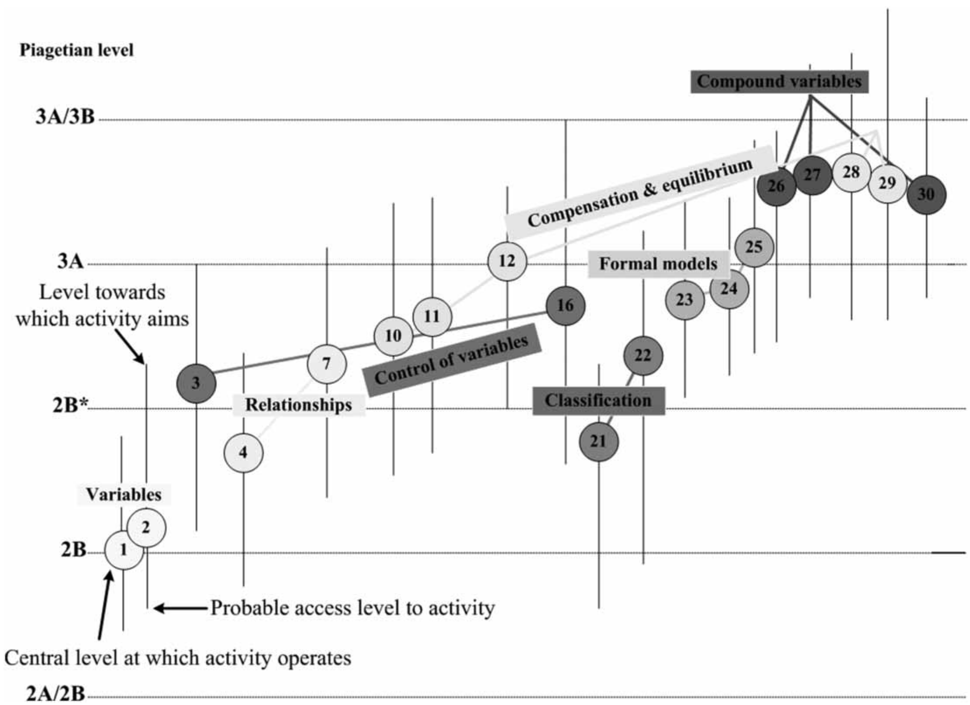


Figure 4. Map of Thinking Science 2 lessons and estimated operating range

Table 1. List of Thinking Science lessons in both programmes

| Lesson number | Lesson name | Thinking Science 1 | Thinking Science 2 |
|---|---|---|---|
| 1 | What varies? | √ | √ |
| 2 | Two variables | √ | √ |
| 3 | The fair test | √ | √ |
| 4 | What sort of relationship? | √ | √ |
| 5 | Roller ball | √ | |
| 6 | Gears & ratios | √ | |
| 7 | Scaling: pictures & microscopes | √ | √ |
| 7a | Bean growth 1 | √ | |
| 7b | Bean growth 2 | √ | |
| 8 | The wheelbarrow | √ | |
| 9 | Trunks & twigs | | |
| 10 | The balance beam | | √ |
| 11 | Current, length & thickness | | √ |
| 12 | Voltage, amps & watts | | √ |
| 13 | Spinning coins | √ | |
| 14 | Combinations | | |
| 15 | Tea tasting | √ | |
| 16 | Interaction | √ | √ |
| 17 | The behaviour of woodlice | √ | |
| 18 | Treatments & 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 & sinking | √ | √ |
| 28 | Up-hill & down dale | | √ |
| 29 | Equilibrium in the balance | | √ |
| 30 | Divers | | √ |



Loucks-Horsley, Hewson, Love, & Stiles, 1998). In contrast, it requires extended opportunities to engage in professional development, with good illustrations of the kind of practice advocated and informative feedback (Osborne & Dillon, 2008). The CASE lessons can be considered little less than time-fillers if the underlying theory is neglected in the training of the teachers.

The training of primary teachers was modelled as far as possible on the original, and since developed, Cognitive Acceleration Professional Development model, proposed by Adey with Hewitt, Hewitt, and Landau (2004). Due to the teachers voluntarily agreeing to become involved in the study and receiving no bursary for doing so (apart from the potential increased cognitive development of their students!), it was decided that the researcher would accommodate the teachers as much as possible, in the facilitation of training in the use of Thinking Science 1. The researcher visited each teacher in his/her own school environment at a time that suited each individual teacher.

There were three types of teaching arrangement at primary school. Some teachers opted to teach the lessons by themselves, others opted for a team-teaching approach in conjunction with the researcher, while others asked the researcher to teach the lessons while they observed.

The teachers who delivered the programme themselves ($N = 4$) were trained by the researcher and four professional development sessions (approximately half-day each) were held prior to the commencement of the teaching of Thinking Science 1. The first two sessions involved unpicking of the CASE philosophy, the five pillars, the underlying theory and schemata of formal operations and the structure of the lessons. After this the teachers were asked to go through three lessons with the materials and equipment provided and to note any areas of difficulty or concern. These areas were addressed in the subsequent visits. The teachers were visited approximately five weeks into the teaching of the programme, in order to support and address any areas of difficulties they may have been having. Towards the end of the school year, the teacher was visited again to review the programme and reflect on the methodology.

In the cases of the team-teaching arrangement ($N = 3$), the delivery of the programme incorporated much of the training. An initial visit involved an overview of the programme, a review of the lessons and planning of how the delivery would work. In general, the way it worked was that the teacher retained overall control of the class and the time, while the researcher re-enforced the CASE methodology. As the teacher and the researcher grew more accustomed to each other's practice, their roles became less defined, more spontaneous and the classes ran smoother. After each Thinking Science 1 lesson in this arrangement, there was a discussion between the researcher and class teacher and an appraisal about what could have been done differently. This was also done in the cases where the researcher delivered the Thinking Science 1 lessons. In this case the class teacher observed the lessons and the interaction of the students with the researcher and lesson. The teacher in this case was also on hand to deal with behavioural issues when they arose.

The preparation of teachers at secondary school was based on a similar ideology as with the primary-school teachers, however, some adaptations were necessary. The science teachers were specialised in science and therefore there was no time required for coverage of content knowledge. This extra time was spent addressing practical issues in the implementation of the programme such as planning and organisation of the term plan to suit the needs of the Thinking Science 2 programme. In addition, some of the training was devoted to managing the time spent on the lessons, to ensure that the maximum value was obtained from the lessons.

Three workshops (approximately half-day each) were held with the teachers implementing the Thinking Science 2 materials. The first workshop involved a review of the methodology, its purpose, background on Piaget's schemata of formal operations and a brief review of results that have been obtained in previous studies. Also, the details of the Thinking Science 1 programme were explained to the teachers and the content to be covered in the programme at primary level. The teachers were given two weeks to work through some lessons, and the second workshop was spent addressing problems that arose and queries that emerged. A final workshop at this introductory stage followed some weeks after the teacher had begun implementing the programme. In addition to a feedback session, there was particular attention paid to the CASE methodology and the teachers' views and experience of using the five 'pillars'.

*Method of Evaluation*

Students' cognitive levels, in both the intervention and non-intervention groups, were tested on two occasions at primary (Points 1 and 2) and two occasions at secondary school (Points 3 and 4), as shown in Figure 5. The tests of cognitive development used were the Science Reasoning Tasks (SRTs) (Shayer, Wylam, Kuchemann, & Adey, 1978), developed by the CSMS team.

The pre-test (SRT I, Spatial Relationships) was administered before the intervention began (Point 1), and the post-test (SRT II, Volume and Heaviness) was administered after the implementation of the Thinking Science 1 intervention, at the end of the primary school year (Point 2). At secondary school, the students' cognitive levels, both in the intervention and non-intervention groups, were tested on two occasions also (Points 3 and 4). The task at Point 3 (SRT III, The Pendulum) was administered before the Thinking Science 2 intervention began. This test acted as a pre-test to the students that were new to the cohort, i.e. those who were not part of either the intervention or non-intervention group at primary school. It was also a delayed post-test for the students that were in the intervention and non-intervention groups at primary school. The post-test (SRT IV, Equilibrium in the balance) was administered at the end of the school year (Point 4), after the completion of the intervention programme.

SRTs are well documented and validated measurements used to determine the cognitive levels of students (Shayer, Adey, & Wylam, 1981). The administration of these SRTs, the correction and the analysis of the results were performed by the researcher,

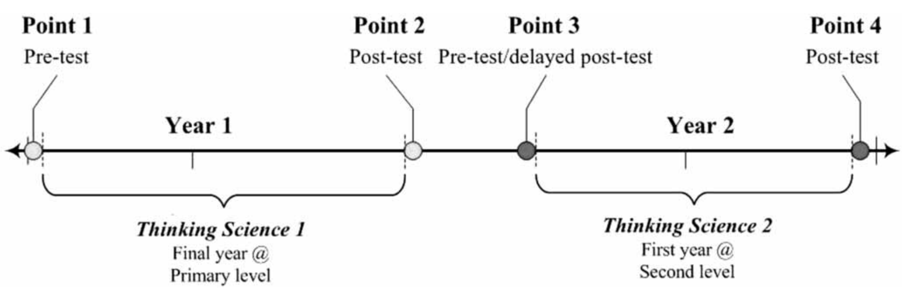


Figure 5. Timeline of implementation and evaluation of Thinking Science 1 and 2 programmes

Table 2. Statistical reliability and validity of Science Reasoning Tasks (SRTs) used in this study

| Test point | Task number and name | Internal consistency (this study) | Test–retest correlation (*n*) | Task–interview correlation (*n*) |
|---|---|---|---|---|
| Point 1 | I Spatial relationships | 0.82 (0.7) | Not assessed | 0.85 (7) |
| Point 2 | II Volume and heaviness | 0.78 (0.7) | 0.84 (67) | Not assessed |
| Point 3 | III The pendulum | 0.83 (0.7) | 0.79 (24) | 0.71 (24) |
| Point 4 | IV Equilibrium in the balance | 0.84 (0.7) | 0.78 (31) | 0.55 (18) |

according to the instructions given by the test developers (Wylam & Shayer, 1978). Table 2 shows the tasks used at various points throughout the study, as well as each tests statistical reliability and validity.

### *Analysis*

In order to evaluate the effectiveness of the intervention programme on cognitive development, rigorous analysis was performed on student responses to the SRTs, used to assess their cognitive levels. The effects of the Thinking Science 1 intervention implemented with the primary school students will be reported first and followed by the effects of the Thinking Science 2 programme on secondary school students. Finally, the effect of the combined programmes on the students who were taught through both programmes will be reported. Table 3 shows the total number of students who were taught through the Thinking Science 1, Thinking Science 2 and both programmes. The students who missed either the pre- or post-tests have been excluded from the analysis.

However, a basic comparison of levels was not seen as a sufficient way to compare these groups due to students' natural cognitive development. To combat this, residual gain score (RGS) analysis was carried out. RGS analysis was used to predict post-test scores of the intervention group, based on the actual pre- and post-test scores of the non-intervention group. If there is any difference between the actual scores obtained by the intervention group, compared with that predicted from the non-intervention group, it can be associated with the intervention. This technique of analysis was used by Adey and Shayer (1994). The RGS method works by using the regression line drawn from the plot of the pre- and post-test results of the non-intervention

Table 3. Number of students in intervention and non-intervention groups at primary school, secondary school and both

| Group | Primary | Secondary | Both |
|---|---|---|---|
| Intervention | 375 | 151 | 28 |
| Non-intervention | 300 | 634 | 49 |

group. Using the equation of the line, the predicted post-test scores for the intervention group can be computed. When the predicted post-test scores are subtracted from the actual scores, the RGS is found. In theory, the RGS of the non-intervention group should distribute around a mean of zero. The RGS of the intervention class will also group around a mean. If the mean is zero, this implies that the intervention had little or no effect on the parameter being measured. A positive mean implies that the intervention has been beneficial, while a negative mean suggests a harmful effect.

## Results

### *Results of the Thinking Science 1 Programme*

Table 4 presents the results from the testing at Points 1 and 2 for the intervention and non-intervention groups. It must be noted that the intervention group for Thinking Science 1 had a higher pre-test mean. The difference between the two groups at this stage was statistically significant ($t(619) = 3.14, p < .01$), however, the difference corresponded to a small effect, with an eta-squared value of 0.02. In the intervention group, there was no statistically significant difference between the male (mean ($M$) = 11.51, standard deviation (SD) = 2.36) and female group ($M$ = 11.45, SD = 2.65) in their pre-test (SRT I) scores ($t(303) = 0.20, p > .05$). This was also true of the non-intervention group ($t(236) = 0.30, p > .05$). At Point 2 testing, the intervention group had a higher mean test score ($M$ = 7.83, SD = 2.52) compared to the non-intervention group ($M$ = 6.57, SD = 2.50). There was a statistically significant difference between the two groups ($t(541) = 5.77, p < .01$).

The Thinking Science 1 programme had an effect size of 0.44 SD, which corresponds to a medium effect size. An effect size of 0.5 SD is a modest effect size and will move the mean score from ‘average’ to that of the top 30% of the ability range. An effect size in the order of 0.4 is regarded by Hattie as the level at which ‘the effects of the innovation enhance achievement in such a way that we can notice’ (2009, p. 17).



Table 4. Pre- and post-test means and mean RGS and standard deviation values of intervention and non-intervention groups at primary school, secondary school and in both primary and secondary school

| Level | Group | $N$ | Pre-test mean (SD) | Post-test mean (SD) | RGS (SD) | Effect size (SD) |
|---|---|---|---|---|---|---|
| Primary | Intervention | 305 | 11.47 (2.56) | 7.82 (2.52) | 1.00 (2.36) | 0.44 |
| | Non-intervention | 238 | 10.72 (2.71) | 6.57 (2.50) | 0.03 (2.29) | |
| Secondary | Intervention | 94 | 2.60 (1.75) | 4.33 (1.81) | 1.07 (1.47) | 0.76 |
| | Non-intervention | 448 | 3.10 (1.83) | 3.50 (1.60) | 0.01 (1.40) | |
| Both | Intervention | 28 | 10.80 (2.30) | 4.95 (2.55) | 1.53 (2.33) | 0.99 |
| | Non-intervention | 49 | 10.63 (2.60) | 3.39 (1.58) | 0.00 (1.54) | |

In terms of RGS, the intervention group had the greatest mean RGS ($M = 1.00$, $SD = 2.36$) compared with the non-intervention group ($M = 0.03$, $SD = 2.29$). The difference between the two groups, in terms of mean RGS, was significant ($t(540) = 4.78$, $p < .01$).

At Point 3 the students were administered another SRT in order to monitor the sustainability of the effect across the transition from primary to secondary school. In this sample there were 131 students who had done the Thinking Science 1 intervention and 99 students that were not part of this group. The mean SRT score for the intervention group was higher ($M = 3.50$, $SD = 2.35$) compared to the non-intervention group ($M = 2.62$, $SD = 1.70$). This difference was statistically significant ($t(228) = 3.16$, $p < .01$). This indicates that the effect of Thinking Science 1 is still evident over three months after the completion of the intervention and that the students who were taught through this intervention are at higher cognitive ability levels, compared to their peers who did not.

In order to gain more insight into the groups that gained the most from the Thinking Science 1 programme, it was necessary to first inspect the mean RGS values of the gender groups. Table 5 shows the mean RGS values of the male and female groups, in both the intervention and non-intervention groups. Within both gender groupings, the intervention group attained greater mean RGSs compared to the non-intervention groups, both significant at the 99% confidence level. In order to assess if the Thinking Science 1 programme had a greater effect on the male or female cohort, we must take a closer look at the data in Table 5. The male group attained a higher mean RGS ($M = 1.23$, $SD = 2.16$) than the female group ($M = 0.89$, $SD = 2.45$). However, this difference was not significant ($t(302) = 1.13$, $p > .05$). In conclusion, it can be said that there was no difference in the mean RGS of the male and female groups in the intervention group. There was also no statistical difference in the mean RGS of the male and females, in the non-intervention group ($t(236) = -0.77$, $p > .05$).

Table 5. Mean RGS and standard deviation values of intervention and non-intervention groups at primary school, secondary school and in both primary and secondary school, according to gender

| Level | Group | Gender | *N* | RGS (SD) |
|---|---|---|---|---|
| Primary | Intervention | Male | 94 | 1.23 (2.16) |
| | | Female | 210 | 0.89 (2.45) |
| | Non-intervention | Male | 129 | 0.14 (2.44) |
| | | Female | 109 | (−0.09) (2.1) |
| Secondary | Intervention | Male | 47 | 0.84 (1.15) |
| | | Female | 47 | 1.3 (1.72) |
| | Non-intervention | Male | 198 | −0.08 (1.26) |
| | | Female | 250 | 0.08 (1.51) |
| Both | Intervention | Male | n/a | n/a |
| | | Female | 28 | 1.53 (2.33) |
| | Non-intervention | Male | 40 | 0.08 (1.61) |
| | | Female | 9 | −0.38 (1.21) |

Table 6. Mean RGS and standard deviation values of intervention groups, based on teaching arrangement

| | Thinking Science 1 | | Thinking Science 2 | |
|---|---|---|---|---|
| Teaching arrangement | *N* | Mean RGS (SD) | *N* | Mean RGS (SD) |
| Team-teaching | 61 | 1.33 (2.29) | 4 | 3.66 (1.74) |
| Class teacher | 165 | 0.83 (2.35) | 55 | 0.79 (1.11) |
| Researcher | 78 | 1.10 (2.44) | 35 | 1.22 (1.66) |

There were two types of primary schools in the study: single sex and co-educational. The males in the co-educational school ($N = 49$) had a higher mean RGS ($M = 1.42$, SD $= 2.12$) than the males in the single-sex school ($N = 45$) ($M = 1.05$, SD $= 2.21$). However, the difference was not statistically significant ($t(92) = -0.84$, $p > .05$). The results for the female group were similar with the females in the co-educational school ($N = 38$) having the great mean RGS ($M = 1.38$, SD $= 2.60$) compared with the females ($N = 172$) in the single-sex school ($M = 0.79$, SD $= 2.41$). However, this difference was also not statistically significant ($t(208) = -1.35$, $p > .05$).

The Thinking Science 1 programme was implemented via three different methods of instruction, namely the lessons were taught by the class teacher, the researcher and by a team-teaching arrangement, which involved a combination of both. The mean RGS for the different teaching arrangements are shown in Table 6. The team-teaching implementation method had the highest RGS ($M = 1.33$, SD $= 2.29$), followed by the researcher ($M = 1.10$, SD $= 2.44$) and by the class teachers ($M = 0.83$, SD $= 2.35$). However, there was no statistically significant difference between the groups at primary school ($F(2, 301) = 1.11$, $p > .05$).

### *Results of the Thinking Science 2 Programme*

The Thinking Science 2 programme, implemented in the first year of secondary school, was assessed with a pre-test (at Point 3) and a post-test (at Point 4). The pre-test means for the intervention and non-intervention groups are shown in Table 4. It can be seen that the pre-test mean for the non-intervention group is higher than that of the intervention group and this difference was statistically significant ($t(540) = -2.45$, $p < .05$). The magnitude of this difference was moderately small ($\eta^2 = 0.03$), as defined by Cohen (1988).

The gains made by the intervention group were greater than the non-intervention group, however, in the order of 1.73 and 0.4, respectively, over the pre- and post-test. The mean RGS of the intervention group ($M = 1.07$, SD $= 1.47$) far exceeded that of the non-intervention group ($M = 0.01$, SD $= 1.40$). The difference in the means was significant ($t(541) = 6.64$, $p < .05$). There was an effect size of 0.76, which corresponds to a large effect size.

At Point 3 there was a significant difference between the gender groups in the intervention group. The female cohort had a higher pre-test score ($M = 3.05$, SD $= 1.97$)

compared with the male cohort ($M = 2.15$, SD = 1.37), and the difference was significant ($t(82.14) = -2.60$, $p < .05$). At the time of post-test, there was also a difference between the two groups, with the female group having the highest score in SRT IV ($M = 4.77$, SD = 2.13) compared to the male group ($M = 3.89$, SD = 1.31). This difference at this stage was also significant ($t(76.39) = -2.40$, $p < .05$). However, in terms of the residual gains made by both groups, although it appears that the female group made higher gains, this difference was not statistically significant ($t(92) = -1.54$, $p > .05$).

Similar to the implementation of the programme at primary school, the Thinking Science 2 programme was also delivered via three teaching arrangements. The mean RGS was greatest for the team-teaching arrangement ($M = 3.66$, SD = 1.74); however, the sample number for this cohort was only 4. This was followed by the RGS mean for the group that were taught by the researcher ($M = 1.22$, SD = 1.66) and lastly followed by the group taught the Thinking Science 2 programme by the class teacher ($M = 0.79$, SD = 1.11). There was a statistically significant difference between the groups in this case ($F(2, 91) = 8.62$, $p < .01$).

### *Results of the Combined Thinking Science 1 and 2 Programmes*

For the analysis of the combined programmes, the non-intervention group was comprised of those students who did not receive any of these programmes, but their cognitive levels were tracked at four points over the two years at primary and secondary school. There were 49 students in this non-intervention group and 28 students in the intervention group.

The pre-test scores (at Point 1) for both groups can be seen in Table 4. The intervention group had a slightly higher mean ($M = 10.80$, SD = 2.30) compared to the non-intervention group ($M = 10.63$, SD = 2.60). There was no statistically significant difference between the two groups at pre-test ($t(62) = -0.12$, $p > .05$). However, at the post-test, after Thinking Science 1, the means differed significantly. The intervention group had the highest mean ($M = 8.31$, SD = 2.16) compared with the non-intervention group ($M = 6.22$, SD = 2.50) and this difference was statistically significant; ($t(40) = 2.91$, $p < .05$).

The SRT administered at Point 3 (the beginning of secondary school) had two purposes essentially. The first was to gauge the cognitive levels of the non-intervention and intervention groups before the second part of the programme, Thinking Science 2. The second purpose of the task was to act as a delayed post-test for the Thinking Science 1 programme, as it was carried out three months after the completion of the programme. The results of this were interesting. Although the mean score of the intervention group was higher ($M = 3.25$, SD = 2.37) than that of the non-intervention group ($M = 2.37$, SD = 1.69), the difference was not significant, ($t(36.79) = 0.74$, $p > .05$).

The final test, SRT IV, carried out at Point 4 was used to gauge the effectiveness of the entire Thinking Science 1 and 2 programmes. The mean of the intervention group ($M = 4.95$, SD = 2.55) was higher than that of the comparable non-intervention group ($M = 3.39$, SD $= 1.58$) yet again. This difference was significant ($t(33.97) = 3.27$, $p < .01$). This result implies that the completion of both programmes had a greater effect over that of just one. The effect size of the Thinking Science 1 and 2 programmes was 0.99 SD which corresponded to a large effect size. An effect size of 1.0 equates to 'advancing children's learning by two to three years' (Hattie, 2009, p. 7).

Regarding RGS analysis, the mean of the intervention group was higher ($M = 1.53$, SD $= 2.33$) than the non-intervention group ($M = 0.00$, SD $= 1.54$). This difference was significant ($t(75) = 3.48$, $p < .01$). There were no males in this group, however, so it is not possible to determine if there were any gender differences in this group.



## Discussion

The results show that the CASE programme has been effective at increasing students' cognitive developmental levels when implemented across the primary–secondary school transition. The effect of the programme over two years is comparable with the published data (Adey & Shayer, 1993, 1994). This research also analysed the effects of the programme taught over two years, the final year of primary and the first year of secondary school. The results showed that at primary level, where half of the programme was delivered, there was an increase in students' cognitive development when compared to the non-intervention group. This was in the order of 0.44 SD. Compared to the results of the original CASE programme delivered over two years, this result implies that the intervention has been very beneficial, with respect to enhancing the pre-transfer students' cognitive development. This is also an evidence that CASE can be implemented successfully at primary school, with the non-specialisation of teachers bearing no disadvantage.

At the primary school, there appeared to be no difference in the improvements made by male or female students in the intervention group. It was also noted that there was no difference due to the type of school that the intervention was delivered in (single sex or co-educational) or in the teaching arrangement.

When tracked into secondary school the difference in cognitive abilities was still evident, three months after the completion of the intervention. However, when the students in the intervention ($N = 96$) and non-intervention ($N = 54$) groups from primary were tracked at the end of secondary school (at Point 4), there was no significant difference in their performance in the SRT $t(148) = 1.27$, $p > .05$). This result shows that perhaps the long-term effects of CASE found by Adey and Shayer are due to the fact that the programme was delivered over two years. Adey and Shayer believed that in order for an intervention to have a tangible effect on cognitive development the intervention would have to last long periods of time, for example, two years in the case of the original Thinking Science materials. This result supports their hypothesis.

The other half of the programme, Thinking Science 2, was delivered in the first year of secondary school. The effect of this was greater than that noted at primary school, with an effect size in the order of 0.76 SD. Despite being behind the non-intervention group prior to the programme, the intervention group made greater gains over the course of the school year. There was no difference in the gains made by the male or female students in the intervention group. It is also worth noting here that the female group prior to the intervention had a higher score (statistically significant) on the SRT. However, despite this there was no difference in the gains made.

However, there was a difference in this case in the teaching arrangement, with the group taught in the team-teaching arrangement making the greater gains. While this was not noted at primary school, it does highlight some interesting points. First off in many ways the CASE programme lends itself nicely to a team-teaching arrangement allowing more teacher time to be spent with smaller groups of students. There is an inference that perhaps there was more opportunity for engagement with cognitive conflict, social construction and metacognition in this arrangement. These of course are key pillars in the CASE methodology and some may suggest that they are required for development.

The greatest gains were made by the students who were taught the programme across the two years and these gains were in the order of 0.99 SD. According to Hattie (2009, p. 7), the gains of this magnitude equate to 'advancing children's learning by two to three years'. This effect size is equivalent to that found in the original CASE experiment (Adey & Shayer, 1993). Their data showed that greatest gains were made by the 12+ male group. There were only females in this sample, so it is not possible to make inferences regarding gender in this case. However, this data implies that the gains are just as significant for the female group in this study.

When the effects of the intervention at primary school were assessed at the end of secondary school (at Point 4), it showed a statistically significant difference between the intervention and non-intervention groups at secondary school ($t(123) = 2.77$, $p < .00$). The group that had done both Thinking Science 1 and 2 ($N = 29$) had a greater post-test mean ($M = 4.98$, SD $= 2.52$) compared to the group that had only done Thinking Science 1 ($N = 96$) ($M = 3.76$, SD $= 1.94$). Adey and Shayer (1993) noticed this in their delayed post-test results, with the experimental group having no overall difference in measures of cognitive development compared to the control group. In this study two possible reasons for this have been identified. One is that the effects of the Thinking Science 1 programme are lost after the first year at secondary school and the other is related to the transfer and the lack of continuity in pedagogy. The group that were exposed to Thinking Science 1 and 2 show no such regression and their development exceeds that in the non-intervention group. These findings indicate the benefits of implementing the CASE programme across the transition.

Firstly, the gains made by the intervention group were substantial and this in some way implies, (although not measured) that the students are equipped with greater capacity to engage with a science curriculum at secondary school. There is evidence from other studies to show that there are far transfer effects of the programme too (Adey & Shayer, 1993) and the benefits are reaped with regards to performance in English and Mathematics also.

With regard to the methodology, the benefits/implications were less quantifiable. To begin with, a group of primary and secondary-school teachers were trained in the use of CASE in the classroom. The training seeped far beyond the shallow in-service model that is often rolled out and required teachers to dig deep into the underlying philosophy that is embedded in CASE. After the study concluded, there was anecdotal evidence to suggest that elements of the CASE pedagogy were still being implemented by some of the primary and secondary-school teachers that were trained as part of the study.

Aside from the gains in cognitive developmental levels, students gained from being taught science through a methodology that was familiar to them and one that provided cognitive challenge. While it is evident that these students benefitted cognitively, there are also implications regarding the transfer. No regression in cognitive development was evident, but for the group that were exposed to the methodology at primary and not at secondary school, their development was not comparable.

However, there are some limitations associated with the implementation of this study, one of the most notable being the small sample size ($N = 32$) of the group who were taught CASE at both primary and secondary schools. Some of the reasons identified for this low number could include that the information that was obtained about feeder primary schools was from head-teachers and teachers at the secondary schools. In some cases primary schools that were identified as potentially having a large cohort of students transferring to selected secondary schools did not have such numbers in the particular years that the study was carried out. In addition to this, it was more difficult to encourage secondary-school teachers to become involved in the intervention programme compared with primary teachers. Some secondary-school science teachers were reluctant to commit due to being already involved in other programmes or unable to dedicate the time to implement the programme over the period of the school year. This is evident in the large number of students' part of the non-intervention group at secondary school, compared to the intervention group. In some cases when the secondary-school teacher committed to teaching the intervention programme one year prior to its start they then were not teaching in the school or that year group when the time came.

A further limitation is connected with the PD model employed in this study. By and large, the training was conducted with individual teachers on a one-to-one basis at their school and so was not the most efficient or cost-effective method. While the team-teaching arrangement proved the most effective in this study, this arrangement was very demanding in terms of time. Replication of this model to other educational interventions may not be possible.

## Conclusion

The aim of this research was to explore if the CASE programme could contribute to enhanced cognitive development, in an Irish context, across primary and secondary schools. The original CASE materials, Thinking Science, were adapted for use at both levels, and the materials were divided into two, namely, Thinking Science 1 and Thinking Science 2. Following teacher training, the programmes were implemented and their effect on students' cognitive development was monitored and analysed in detail. The overall success of the combined Thinking Science 1 and Thinking Science 2 programmes was in accordance with the original Thinking Science materials. The effect size of the combined programmes was just under 1SD, similar to that noted by Shayer. The programme implemented at primary school also showed positive effects in terms of enhancement of cognitive development of students, with an effect size of 0.4 SD. The programme implemented in the first year of secondary school had an effect size of 0.77 SD.

To summarise, the CASE programme was implemented across the primary–secondary school transition. The programme yielded very positive results in terms of students' cognitive development, and the combined effect of both programmes was large.



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