Transforming Science in the Irish Primary School – CASE and Metacognition

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Abstract

Transforming Science in the Irish Primary School – CASE and Metacognition

The development of Irish primary students' higher-order thinking skills has been highlighted as an area of concern within the teaching of science. This study proposed that the Cognitive Acceleration through Science Education (CASE) methodology could be as a suitable approach to address these concerns. CASE has previously shown to have positive effects on Irish primary students' thinking skills; therefore, the intention of this research was not to assess the effects of the methodology on the students, but to evaluate the teachers' implementation of the lessons. The aims of this study were to:

- Assess whether the CASE methodology could be integrated into the teaching of science at all levels in an Irish primary school,
- Evaluate the teachers' implementation of the lessons with the aim of identifying areas of difficulty

This study, which lasted for two years, employed a case study design and involved a large primary school of 31 class teachers and over 900 students. The existing CASE activities, which were initially designed for use in the educational system of England and Wales, were adapted and made suitable for use with Irish primary students. Analysis indicates that there was a large degree of overlap between the objectives of the CASE lessons and the primary science curriculum in relation to scientific content and skills. The activities were mapped onto the curriculum to create a continuous programme of thinking though science for the Irish primary school.

The findings of this study indicate that the teachers generally had positive attitudes towards the methodology and improved in their implementation of the lessons as the programme progressed. However, the teachers were unable to engage their students' in metacognitive discussions throughout the programme. Further analysis highlighted that this was due to a lack of understanding of the concept of metacognition. The majority of teachers were unable to distinguish between cognitive extension during the lesson (CE) and metacognitive reflection (MT), and only three teachers referred to metacognition as consciousness of thinking. This study advocates the integration of the CASE methodology into the teaching of primary science in Ireland and recommends that future implementation should focus on developing teachers' knowledge of, and pedagogies in the context of metacognition.

Glossary

Notation	Meaning
ACTS	Activating Children's Thinking Skills
BLOT	Bond's Logical Operations Test
CA	Cognitive Acceleration
CAME	Cognitive Acceleration through Mathematics Education
CASE	Cognitive Acceleration through Science Education
CATE	Cognitive Acceleration through Technology Education
CC	Cognitive Conflict
CE	Cognitive Extension
CMDS	Classical Multidimensional Scaling
CoRT	Cognitive Research Trust
CP	Concrete Preparation
CSMS	Concepts in Secondary Mathematics and Science
DES	Department of Education and Skills
GCSE	General Certificate of Secondary Education
HOTS	Higher Order Thinking Skills
IAEP	International Assessment of Educational Progress
IE	Instrumental Enrichment
INTO	Irish National Teachers Organisation
L	Lesson
LT	Let's Think
LTEY	Let's Think Early Years
LTTS	Let's Think Through Science
M	Metacognition
MDS	Multidimensional Scaling
MT	Metacognitive Thinking
NCCA	National Council for Curriculum and Assessment
OECD	Organisation for Economic Co-operation and Development
PCSP	Primary Curriculum Support Programme
PD	Professional Development
PDST	Professional Development Service for Teachers
PSC	Primary Science Curriculum
Q	Questionnaire
RGS	Residual Gain Score
SAT	Standard Assessment Test
SESE	Social, Environmental and Scientific Education
SESS	Special Education Support Service
SRT	Science Reasoning Task
T	Teacher
TAO	Teach Advance Online
TIMSS	Trends in International Mathematics and Science Study
TS	Thinking Science
ZAP	Zone of Acceptable Proximity
ZPD	Zone of Proximal Development

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Introduction to the Study

With the use of modern technology, access to large bodies of information is now readily available. From an educational viewpoint, this has reduced the 'value' of rote learning and memorisation of vast quantities of facts. Students need to be equipped with effective problem solving and reasoning skills to contend with the rapid pace of technological advancement and ever-growing amount of scientific information available (Zohar, 2013a). Therefore, education should move beyond providing students with merely factual knowledge, and assist students in developing the skills that will enable them to acquire and process new knowledge.

The Irish primary school curriculum highlights the importance of preparing students for 'life-long learning', and places equal emphasis on developing students' knowledge of concepts and higher order thinking skills (HOTS) (Department of Education and Science, 1999a). McGuinness (2005) defines higher-order thinking as "*the need for learners to go beyond the mere recall of factual information to develop a deeper understanding of topics, to be more critical about evidence, to solve problems and think flexibly, to make reasoned judgments and decisions rather than jumping to immediate conclusions*" (p.107). The Organisation for Economic Co-operation and Development (OECD) highlight that these skills are essential in developing a scientific literate society to promote technological and scientific advancement (OECD, 2013).

Recent studies have shown that Irish students' HOTS are under promoted within the teaching of science (NCCA, 2008; TIMSS, 2012). The Trends in International Mathematics and Science Study (TIMSS, 2011) study demonstrated that Irish students' knowledge of scientific concepts was in line with international averages but that their ability to reason or apply their knowledge fell below international averages. The National Centre for Curriculum Assessment (NCCA, 2008) recommends that "a culture of thinking" be encouraged as an educational goal in Irish primary science that will go beyond knowing and memorising to produce a deeper level of understanding. Teachers should be provided with the supports to develop their pedagogical knowledge in relation to the teaching of thinking, with the aim of increasing students' HOTS (NCCA, 2008).

This study aims to address the concerns regarding the development of Irish students' reasoning skills, and proposes that the teaching of thinking can be integrated into the teaching of science in Ireland. Numerous approaches have been developed which focus on the explicit teaching of thinking. Examples include De Bono's *Cognitive Research Trust* (CoRT) (De Bono, 1976), *The Somerset Thinking Skills programme* (Blagg *et al.,* 1988) and *Activating Children's Thinking Skills* (ACTS) (McGuinness, 2000). One of the most successful and well-evaluated programmes is the Cognitive Acceleration through Science Education (CASE) methodology. The CASE methodology (Adey *et al*., 1989), which is embedded within the context of science, accelerates students' cognitive development and so increases their ability to think efficiently. CASE has continuously shown to have positive effects on students' thinking abilities in Ireland and elsewhere (Adey *et al*., 2002; Gallagher, 2008; McCormack, 2009). This study proposes that the CASE methodology may be a suitable approach to address the concerns highlighted regarding the under development of Irish students thinking skills. Hence, the aims of this research project are to:

1. Assess whether the CASE methodology can be integrated into the teaching of science at all levels in an Irish primary school
2. Evaluate the teachers' implementation of the CASE methodology with the aim of identifying areas of difficulty.

The aim of this research was not to assess the effects of the CASE methodology on students' thinking skills but to evaluate the teachers' implementation of the CASE lessons and in particular their implementation of each pillar of the CASE programme. As the study progressed, it was found that teachers had difficulty with the pillar of metacognition; the study was then refocused on identifying teachers' understanding of the concept of metacognition and on how they implemented this within their classrooms. Identifying areas of difficulty for the teachers can be used to inform any future implementation of the CASE methodology in Irish schools.

This thesis comprises of eight chapters. Chapter 1 provides an overview of the teaching of science in Irish primary schools and specifies the rational and objectives of the study. Chapter 2 discusses the theoretical underpinnings of the CASE methodology, and its effects on students' cognitive development and general thinking abilities. The classroom approaches to the CASE methodology and a professional development programme are also described. An overview of the research methodology is provided in Chapter 3, including the analysis of small-scale pilot programme involving four teachers, the adaption of the existing CASE materials for use in the Irish educational system and an overview of data collection methods employed during the study. Chapter 4 describes the analysis of the data sources collected during the whole-school implementation phase of the study.

Within Chapter 5, a brief overview of the teacher cohort is given, including the participating teachers' scientific background and confidence regarding the teaching of science. Chapter 6 discusses the teachers' implementation of the CASE materials using the data collection methods and analysis described in Chapters 3 and 4 respectively. Having identified the pillar of metacognition as an area of difficulty in CASE, Chapter 7 focuses on the teachers' understanding of the concept of metacognition and their ability to engage their students in metacognitive discussions. Finally, Chapter 8 presents the main findings of the study and its implications for future development and integration of CASE within Irish primary schools.

Chapter 1

Science in Irish Primary Schools

Introduction

In Ireland, primary education involves an eight-year programme, which begins between 4 and 5 years of age. Although there are formal literacy and numeracy tests, currently there is no formal assessment in science in the Irish primary education system. Children finish their primary school education at the end of 6th class, the equivalent of which is Year 7 in the English system. This chapter is divided into three sections. The first section (1.1) provides an overview of the science curriculum currently taught in Irish primary schools. In the second section (1.2) a number of studies are reviewed which evaluate the implementation of revised science curriculum, introduced in 1999. Concerns regarding the development of Irish students higher-order thinking skills are highlighted, which gives rise to the rational for this study discussed in the final section (1.3).

1.1 Science in Irish Primary Schools

In Ireland, the current Primary Science Curriculum (PSC) was introduced in 1999 (DES, 1999b) after a number of concerns were highlighted regarding the *Curaclam na Bunscoile* (DoE, 1971) in operation at the time. Under the *Curaclam na Bunscoile*, science was only compulsory at the 5th and 6th class levels and focused heavily on the topics of biology and botany (Varley *et al.,* 2008). A report by the Irish National Teachers Organisation (INTO) highlighted the inadequacies of primary science including the lack of curriculum content, inadequate provision of materials and a lack of in-service education (INTO, 1992). The report also suggested that many primary teachers did not have sufficient knowledge of science to foster scientific inquiry. A review of the curriculum (INTO, 1996) revealed that just over half of the teachers surveyed were teaching primary science, and less than half of respondents said that their students conducted simple scientific experiments. Irish students' performance in science at international level was also underwhelming. *The International Assessment of Educational Progress* (*IAEP*, 1989) study highlighted that Irish students' science achievement was below average and that, while the majority of Irish 13 year olds demonstrated that they knew everyday facts, they could not design and analyse experiments, interpret relationships and draw conclusions. The findings of the *Third International Mathematics and Science Study* (TIMSS) carried out in 1995 (Martin *et al.,* 1997) revealed that Irish students' overall science achievement was above average, however they did not perform particularly well in physical sciences. In an effort to increase students' achievement and promote the teaching of science in Irish schools, the revised primary science curriculum was revised in 1999 (DES, 1999a).

1.1.1 The Revised Primary School Science Curriculum

A revision of the entire primary curriculum was carried out in 1999, and formally implemented in 2003. Within the curriculum, equal importance is placed on the development of students' knowledge of concepts and skills. Students are encouraged to develop the abilities to think critically and to "*learn how to learn*" (DES, 1999a). Under the revised curriculum, science is integrated with Geography and History to form Social, Environmental and Scientific Education (SESE). The development of HOTS is emphasised throughout the primary curriculum, but is highlighted as particularly relevant in the teaching of the three SESE subjects. The HOTS listed in the curriculum include '*summarising, analysing, making inferences and deductions, and interpreting figurative language and imagery*' (DES. 1999a p.16).

The primary science curriculum aims to develop students' scientific literacy, to foster positive attitudes towards science and to develop students' understanding of the role science plays in society (DES, 1999b). The curriculum places equal importance on the development of students' knowledge of concepts and scientific skills, which should be promoted through engaging in scientific investigations. The main aims of the primary school science curriculum are to:

- *Develop knowledge and understanding of scientific and technological concepts through the exploration of human, natural and physical aspects of the environment;*
- *Develop a scientific approach to problem-solving which emphasises understanding and constructive thinking;*
- *Encourage the child to explore, develop and apply scientific ideas and concepts through designing and making activities;*
- *Foster the child's natural curiosity, so encouraging independent enquiry and creative action;*
- *Help the child to appreciate the contribution of science and technology to the social, economic, cultural and other dimensions of society;*
- *Cultivate an appreciation and respect for the diversity of living and non-living things, their interdependence and interactions;*
- *Encourage the child to behave responsibly to protect, improve and cherish the environment and to become involved in the identification, discussion, resolution and avoidance of environmental problems and so promote sustainable development;*
- *Enable the child to communicate ideas, present work and report findings using a variety of media*

(DES, 1999b p.11)

The aims of the curriculum reflect the constructivist approach to learning. Students are encouraged to become active in the acquisition of their own knowledge by participating in scientific investigations. Through modifying their existing ideas and constructing their own understanding, students engage in more meaningful learning (DES, 1999b).

In relation to content, the primary science curriculum encompasses a range of scientific concepts and skills. The curriculum aims to develop students' basic knowledge of scientific concepts in the domains of biological and physical sciences. The science content is divided into four strands namely: Living Things, Energy and Forces, Materials and Change, and Environmental Awareness and Care. Each strand is sub-divided into 'strand units', which are almost identical at each class level, as shown in Table 1.1. The curriculum is based on a spiral approach, so that the same topics can be explored throughout primary school in increasing complexity and detail.

Table 1.1: Strands and stand-units of the Revised Primary Science Curriculum (DES, 1999b)

Strand	**Strand units**	
Living Things (Biology)	**Junior classes** • Myself • Plants and animals	**Senior classes** • Human life • Plants and animals
Energy and Forces (Physics)	• Light • Sound • Heat • Magnetism and electricity • Forces	
Materials (Chemistry)	• Properties and characteristics of materials • Materials and change	
Environmental awareness and care (Ecology and Environmental Sciences)	**Junior classes** • Caring for my locality	**Senior classes** • Environmental awareness

The curriculum also emphasises the development of students' procedural understanding, which is encouraged through the skill sections of '*Working scientifically*' and '*Designing and making*'. Particular importance is placed on developing the skills of:

- *Questioning*
- *Observing*
- *Predicting*
- *Investigating and experimenting*
- *Estimating and measuring*
- *Analysing*
- *Interpreting*
- *Recording and communicating results.*

The development of these skills is highlighted as an important factor in the process of knowledge acquisition, in that the development of one enhances and promotes the other:

> *"Learning science will help children to develop the practical skills of investigation and of designing and making. As children use and apply these skills they will learn to deal with more complex concepts and scientific knowledge*." (DES, 1999c p.21)

In the 'Designing and making' section, students are encouraged to apply their scientific knowledge and skills to practical problems, in which they are encouraged to plan, create and evaluate their ideas to devise a solution. Engaging in practical activity is necessary to develop students' scientific skills and is also highlighted as an important aspect in students' cognitive development, as experience with physical objects is essential in developing the mental representations necessary for future learning (DES, 1999b). Language also contributes to conceptual and skill development, as students are encouraged to formulate questions, predict, explain, discuss and evaluate their learning processes. The curriculum suggests a variety of approaches and methodologies to facilitate students' learning and investigations in science. These include whole-class and small-group activities, open and closed-ended investigations (DES, 1999c). Teachers are encouraged to use students' existing ideas and interests as starting points for scientific inquiry with the aim of developing their knowledge of scientific concepts and ability to employ scientific skills.

1.1.2 Teacher support

The introduction of the revised curriculum was supported by the Primary Curriculum Support Programme (PCSP), which offered in-service to all teachers in the academic year 2002/2003. In-service consisted of 2 seminar days followed by 1 day school planning. During Workshops teachers engaged in hands-on activities that they could implement in their classrooms (Varley *et al., 2008*). Teachers also received a copy of the Teacher Guidelines (DES, 1999c), which contained suggested approaches to planning for science at whole-school and classroom level, offered advice on how to approach the various strands and skills sections of the curriculum, and included over forty exemplars of effective implementation of the science curriculum.

Currently professional development in science is not compulsory for primary teachers. Informal professional development courses are offered by independent bodies however, these are not accredited. A list of recent professional development courses in science education in Ireland is presented in Table 1.2. which have been organised in collaboration with the teacher-education colleges and/or government bodies. Teachers can also participate in short twenty-hour summer courses approved by the Department of Education and Skills for which teachers are awarded three days annual leave (EPV), which currently are focussed on literacy and numeracy. In the case of such DES recognised summer courses, the main criterion is that the revised primary curriculum is addressed in the course, but any subject can be advanced.

Table 1.2: Recent professional development course in science for primary teachers

Professional Development Course	Provider	Source
South Kerry Science Project (SKSP) (2004-2009)	St. Patrick's College / Irish-American Partnership / DES	http://www.hse.ie/eng/services/publications/HealthProtection/Public_Health_/Kerry_Life_Education_Evaluation_Report.pdf
Western Seaboard Science Project (WSSP) (2009 - date)	St. Patrick's College / Irish-American Partnership / DES	http://eprints.nuim.ie/4008/
STEM teacher education Programme (2012 - 2016)	DCU / SPD / Royal Dublin Society	http://www.rds.ie/stem
Fibonacci Project	European Union	http://fibonacci-project.eu
Discover Primary Science and Mathematics (DPSM)(on-going)	Science Foundation Ireland	http://www.primaryscience.ie
Exploring our energy	Sustainable Energy Authority of Ireland (SEAI)	http://www.seai.ie/Schools/Primary_Schools/
SOPHIA Project (2006-2009)	European Union	

1.2 Review of the revised primary science curriculum

The *National Council for Curriculum and Assessment* (NCCA) carried out a review assessing the implementation of the revised primary science curriculum (Varely *et al*., 2008). The first phase of the review examined students' experiences of primary school science, and noted that, in general, students had a positive attitude towards science, and enjoyed hands-on science activities including 'designing and making'. Students also had positive attitudes towards group-work, the use of ICT and working outdoors (Varley *et al., 2008*). However, areas of concern were highlighted including the under-development of students' scientific skills and a lack of pupil-led investigations and opportunities for 'designing and making'. The review also highlighted the infrequency with which students engaged with the strand-units of 'Forces' and 'Properties and characteristics of materials'. The results of a survey carried out by the NCCA (2008) into the implementation of the primary school curriculum also referred to students' scientific skill development as an area of concern. The report suggested that students were infrequently provided with opportunities to develop such skills as investigating and experimenting, estimating and measuring, and analysing. This was due to a lack of child-led investigations, opportunities for designing and making, and an over-reliance on teacher demonstrations (NCCA, 2008; Varley *et al., 2008*). This analysis indicates that, although the science curriculum emphasises the importance of developing students' scientific skills, these are under-promoted in the teaching of science. The infrequency with which Irish students engage with scientific investigations and design and make activities indicates that students' higher-order thinking skills are not being developed to their full potential (NCCA, 2008).

In relation to teacher confidence and competence, a survey carried out by the *Irish National Teachers Organisation* (INTO) in 2005 revealed that almost all primary teachers considered the in-service provided by the PCSP either very satisfactory or satisfactory. However, in the same survey, over half of all respondents felt that they needed further in-service in science, the highest of any subject at primary level (INTO, 2005). The *Department of Education and Science* (DES, 2012) carried out a study into the implementation of the revised science curriculum in forty primary schools in Ireland. Teachers in each of the schools were observed teaching one of the strands of the curriculum to their students. The study suggested that teachers' knowledge of science concepts and skills was either good or very good in most cases, and that teachers were able to relate science topics to everyday life. However, teachers' knowledge of physical science concepts was rather limited (DES, 2012). Furthermore, almost half of the lessons observed were judged to be fair or poor in terms of eliciting students' existing ideas and in allowing students to engage in scientific investigations (DES, 2012), two aspects that are heavily emphasised within the curriculum documentation. The report highlights areas for improvement including providing more opportunities for problem-solving and for students to engage in open-ended investigations.

At international level, Irish students participated in the *Trends in International Mathematics and Science Study* (TIMSS) in 2011. Over 600,000 students took part in the study from 50 countries worldwide. Irish participants were from 4th class, between the ages of 9 and 10 years. Students were assessed in relation to their scientific content knowledge and their cognitive abilities. The content domain comprised of three sections; life science, physical science and earth science. There was a large degree of overlap between the test items, which were part of the TIMSS survey, and the objectives of the Irish primary science curriculum for 4th class (Murphy, 2013) suggesting that Irish students should be familiar with almost all of the concepts covered in the study. The cognitive abilities consisted of knowing, applying and reasoning.

> *Knowing covers the student's knowledge of science facts, procedures, and concepts. Applying focuses on the student's ability to apply knowledge and conceptual understanding in a science problem situation and reasoning goes beyond the solution of routine science problems to encompass unfamiliar situations, complex contexts, and multi-step problems* (Martin *et al.,* 2012 p.142).

Overall, Irish students were ranked 22nd out of 50 participating countries, with 17 countries achieving mean scores significantly higher (Martin *et al.,* 2012). Irish students' achievement in the three content areas was above international averages, however they did not perform particularly well in the area of physical science. In terms of cognitive abilities, students' reasoning skills were quite poor and significantly below the international average. Only 35% of Irish students reached the 'high international benchmark', indicating that only this proportion of students was able to apply their scientific knowledge and understanding to explain everyday abstract concepts. Irish students' performance in the cognitive domain was similar to that of the other participating countries in that their knowledge of concepts was better than their ability to reason or apply their knowledge (Martin *et al.,* 2012). A significant outcome of the TIMSS 2011 study was that Irish students' overall science achievement was almost identical to the overall achievement of the participants in the 1995 study. This implies that there has been little change in students' achievement in science despite the introduction of the revised science curriculum in 1999.

A comparison of the participating teachers was also conducted as part of the TIMMS study. In relation to confidence, the proportion of Irish teachers who felt very prepared to teach science was below the international average, particularly in the areas of life and physical sciences (Martin *et al.,* 2012). The study also highlighted that Irish teachers were generally more confident teaching mathematics than science (Clerkin, 2013). Teachers were asked to rate their confidence relating to several aspects of teaching science and mathematics, as shown Table 1.3. The figures represent the percentage of students whose teachers were 'very confident' with each aspect. Irish teachers' confidence was below international averages for all aspects related to the teaching of science. Internationally, teachers were more confident with the same aspects of teaching when they are related to mathematics however, this disparity is even greater for Irish teachers, as shown in Table 1.3. The results also highlight that all teachers participating in the study were not very confident in relation to providing challenging tasks for their students.

Table 1.3: Percentages of students' whose teachers reported being *very confident* teaching particular aspects of mathematics and science, Irish and TIMMS International average (Clerkin, 2013)

	Maths		Science	
	Ireland	International Average	Ireland	International Average
Answering pupils' questions about maths/ science	92	84	39	62
Provide challenging tasks for capable students	63	59	28	43
Adapt teaching to engage pupils interests	63	65	44	63
Help pupils appreciate the value of learning maths/ science	61	69	54	68
Show pupils a variety of problem solving strategies	70	75		
Explain science concepts or principles by doing science experiments			44	51

The TIMSS 2011 study also highlighted that Irish teachers' participation in continuous professional development is considerably below international averages, particularly in the areas of classroom pedagogy and instruction, assessment, and addressing individuals needs, as shown in Table 1.4 (Martin *et al.,* 2012).

Table 1.4: Percentages of students' whose teachers participated in continuous professional development related to particular aspects of science teaching (Martin *et al.,* 2012).

CPD Area	Ireland	International Average
Content	23	35
Pedagogy/Instruction	16	34
Curriculum	24	34
Integrating ICT	17	28
Assessment	9	27
Addressing individuals needs	12	32

1.3 Rational for the study

The rational for this study is based upon the NCCA's (2008) concern that Irish primary students' HOTS are under emphasised within the teaching of science. These concerns have been supported by the demonstration of poor reasoning skills in the TIMSS 2011 study. Irish students exhibit that they have a sound knowledge of scientific concepts but are unable to apply their understanding, which the Irish curriculum emphasises as a central aspect of learning.

> *One way to judge the effectiveness of learning is to look at the child's ability to apply what he or she has learned in dealing with problems, choices, situations and experiences that are unfamiliar* (DES, 1999a p.16)

The NCCA (2008) recommends that teachers be provided with the supports to develop their pedagogical knowledge in relation to the teaching of thinking, with the aim of increasing students' HOTS. Teachers should be supported in promoting "*a culture of thinking, questioning and understanding among children as educational goals*". (NCCA, 2008 p.204). The NCCA suggests that:

> *This would move children's thinking to a higher level of reflection and analysis (thus going beyond knowing and memorising) so that children could apply thinking skills to produce deeper understanding of a topic or subject.*
>
> (NCCA, 2008 p.205)

Numerous programmes have been developed which aim to increase students' thinking skills. One of the most successful approaches is the Cognitive Acceleration through Science Education (CASE) methodology (Adey *et al*., 1989). The CASE methodology, which draws on developmental psychology, goes beyond mastering bodies of information and focuses on accelerating students' progress through the developmental stages as described by Piaget (1963). Previous studies have shown the CASE methodology to have positive effects on Irish students' cognitive development and thinking skills (Gallagher, 2008; McCormack, 2009). This study specifically focuses on the suitability of integrating the CASE methodology into the teaching of science in Irish primary schools and identifies areas of difficulty for teachers. Findings from this study can be used to inform any future implementation of the CASE methodology in Irish primary schools. The next chapter provides an overview of the CASE methodology and its' effects on students thinking abilities and academic achievement.

Chapter 2

The CASE Methodology: Development and Effects

Introduction

The previous chapter highlighted that the development of students' thinking skills is an area of concern within the teaching of primary science in Ireland. The main aim of the CASE methodology is to accelerate student's cognitive development and so increase their ability to think efficiently. The CASE methodology draws on developmental theories of Piaget and Vygotsky as they "appear to offer fruitful avenues towards our goal of devising educational methods for the acceleration of cognitive development" (Adey, 2004 pg. 396). This chapter begins by discussing the developmental theories of Piaget and Vygotsky and their influence on programmes that have shown to be successful in promoting and enhancing cognitive development. The CASE methodology is then described, including some evidence of its effects on student's thinking abilities and academic achievement. Finally, the pedagogical methods of the CASE methodology are described and the preparation of teachers through professional development programmes is discussed.

2.1 Piaget's theory of cognitive development

According to Piaget, the mind consists of cognitive structures, known as schemata (Piaget, 1952). A schema is defined as "the mental representation of an associated set of perceptions, ideas, and/or actions" (Woolfolk, 1987 p.). We use these schemata to organize new information according to common characteristics. Schemata begin to develop from birth, although only a few are available to a small child, and they are quite primitive. As a child becomes active in their environment, existing schemata are adapted to incorporate new information. According to Piaget (1952), it is organisation of, and adaption to the environment that drives cognitive development.

Adaption of schemata involves the simultaneous processes of assimilation and accommodation. Assimilation is the process whereby new information is integrated into an existing schema. Assimilation allows for growth of the child's current schema, but does not modify them in any way (Piaget, 1952). When a child assimilates new information, they are said to be in a state of equilibrium. The child can shift to a state of dis-equilibrium when they encounter new information that cannot be integrated into their existing schema. Through the process of accommodation, existing schema can be altered, or new schema constructed to assimilate this information. If the cognitive demand of the task is too low, very little accommodation occurs. If the demand is too high, accommodation is not possible. The development of new schema is a gradual process, which happens over many years. Piaget proposed the idea of 'stages' of cognitive development depending on the level of development of a child's schema (Piaget, 1963).

Piaget's theory divides cognitive development into 4 major stages: sensori-motor, pre-operational, concrete operational, and formal operational. Each stage characterises the mental abilities and limitations of a child in that stage. Piaget established age norms at which a child enters each stage as can be seen in Figure 2.1. However, these ages are only rough estimates and the age at which a child enters a stage varies from individual to individual, and from culture to culture (Wadsworth, 1987).

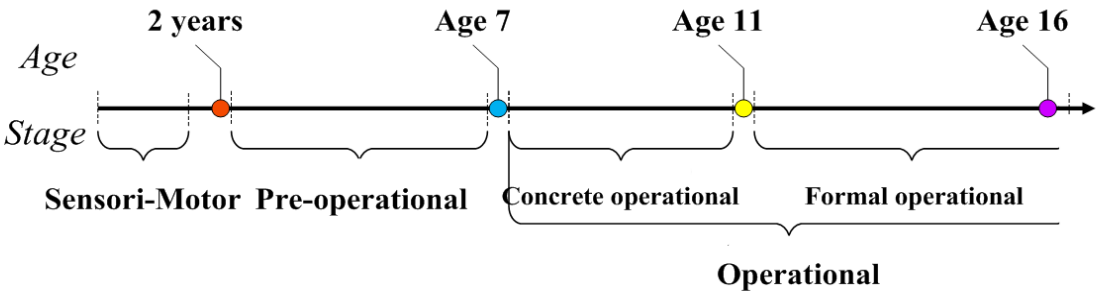

Figure 2.1: Time-line of Piagetian stages of development (Taken from McCormack, 2009)

The sensorimotor stage begins at birth and lasts for about 2 years. In this stage, the child learns about their environment through the sensori-motor skills they were born with i.e. looking, grasping, sucking. Towards the end of this period the child is genuinely interested in their environment and begins to find new ways to explore. Once the child reaches a level where they begin to develop thought and language, they transition into the second major developmental stage, the pre-operational stage (Piaget, 1963).

In the pre-operational stage, the child's thought becomes more structured and less dependent on the sensori-motor actions. The early part of this stage is characterized by the child being egocentric and non-communicative, but they become more social towards the end of this stage. Language develops at around 2-4 years, and the child becomes increasingly able to internally represent events. Thinking in a pre-operational child displays centration, in that the child tends to fix on one aspect of the situation or objects and ignores the other aspects. The schemata of a pre-operational child are quite primitive and underdeveloped. As the stage progresses the schemata become more complex but are still not fully mature. One major limitation of this stage is that the child is unable to reverse operations. In an example taken from Ginsburg and Opper (1987), a pre-operational child is presented with 2 identical beakers (A and B), which are both filled with equal amounts of liquid. The child is then asked whether the 2 beakers contain the same amount of liquid or not. If the child agrees that both beakers are equal, the liquid from beaker B is poured into beaker C, which is shorter and wider than the original 2 beakers. Again, the child is asked whether the 2 beakers, this time A and C, contain the same amount of liquid. A pre-operational child fails this task by answering no as they cannot follow transformations and solely focuses on the heights of the liquid.

As the child's reasoning processes become more logical, they move into the operational stage, which is divided into concrete and formal operational thought. In this stage, the schemata necessary for science and mathematics fully develop. A concrete operational child, which ranges from the ages of about 7 – 11 years, can perform concrete operations, which, in the most general sense, are actions performed on objects to bring them into classes of various orders or to establish relations between them (Inhelder & Piaget, 1958). A concrete operational child can also reverse operations and, as the stage progresses, comprehends conservation. However, a child in the concrete operational stage can only be successful in problems dealing with objects present in the real world and cannot grasp hypothetical or entirely verbal problems.

According to Piaget, the most sophisticated stage of cognitive development is that of formal operational thought. In theory, the schemata reach maturity at about 15/16 years. The most important features of the formal operational stage are the adolescents' ability to use hypothetical reasoning and to perform controlled experiments. An adolescent in the formal operational stage bases their reasoning with hypotheses and propositions rather than on 'real' data alone as in the concrete stage (Inhelder & Piaget, 1958). They have the ability to control variables and to comprehend the relationships between them, including ratio, proportion, compensation, equilibrium, correlation and probability. It is in the formal operational stage where the schemata become fully developed. However, not everyone will reach full maturation in every schema (Wadsworth, 1987)

2.1.1 Development of Schema

Inhelder and Piaget (1958) carried out extensive research into the development of the schema that describe the qualities of thinking at the different stages of cognitive development. Some of the significant schema necessary for science and mathematics exist at a very early age and develop into complex schema at the formal level. While some primitive forms of schema are present in the sensori-motor stage, such as classification and causality, most schema do not begin to develop until the pre-operational stage. The schema developed in each stage can be seen in Table 2.1 and the explanation and development of each schema is now discussed in this section.

Table 2.1: Schemata developed in each stage of development

	Classification	Seriation	Causality	Time Sequence	Spatial Perception	Conservation	Combinatorial Thinking	Control of Variables	Ratio/Proportionality	Probability	Correlation	Equilibrium	Formal Modelling
Pre-operational	✓	✓	✓										
Concrete Operations	✓	✓	✓	✓	✓	✓	✓						
Formal Operations	✓						✓	✓	✓	✓	✓	✓	✓

a) Schemata of pre-operational and concrete operational stages

i. Classification

Classification is the ability to place a number of objects into groups, according to shared characteristics. This schema begins to develop in the sensori-motor period when children have a primitive sort of motor classification which they apply to their environment e.g. objects that move/don't move. An early pre-operational child, from the ages of about 2 – 4 years has difficulties classifying objects by a clear rule and instead uses a method known as 'small partial alignment'. With this method, some objects are grouped together but there is no clear rule. For example, a child given a number of different coloured shapes may place some of the triangles in a line but organize the other objects using no clear rule. They display some understanding of the task but do not apply the rule to all of the objects in the set (Piaget, 1952).

A more developed pre-operational child, from about 5 to 6 years, has not only mastered the ability to classify objects using a clear rule, but they can also divide the larger sets into subsets. For example, a child in this stage presented with the same shapes as before not only separated the shapes into polygons and rounded shapes but also into squares/triangles and circles/half circles (Ginsburg & Opper, 1987). One of the major limitations of this stage is that a pre-operational child struggles with the concept of class inclusion, that is, they cannot deal with the parts and the whole at the same time. Once the child divides the objects into a sub-group, he finds it difficult to see that the sub-group is still a part of the overall larger group from which it was created. Inhelder and Piaget (1958) use the example of a box containing about 18 different coloured wooden beads. The child answers correctly when asked to divide the beads into groups of different colour but fails when asked 'are there more brown beads than wooden beads?' The pre-operational child fails to see that one is a subset of the other.

A child in the concrete operational stage is capable of classifying objects into sets and sub-sets and of comprehending inclusion. However, a child in this stage is unable to give the correct answer when asked the same questions about hypothetical situations/objects. The child’s ability to classify is limited to concrete objects. A child in the concrete operational stage also has no combinatorial system linking sub-sets of classes. To a child in this stage, an item belongs to the class with which it is included at a given moment. The schema of classification continues to develop into the formal operational stage. A child in this stage is capable of understanding class inclusion and of combinatorial thinking. A formal operational child can also comprehend the links between sets and variables including ratio and proportionality (Piaget & Inhelder, 1958).

ii. Seriation

Seriation is the ability to put objects in increasing (or decreasing) order, so that each object is greater than the one before. When asked to place a number of different length sticks (A-J) in order from smallest to biggest a child in the early pre-operational stage cannot compete the task (Ginsburg & Opper, 1987). Some children produce random arrangements and others are able to order some of the sticks but not all of them. Some children produce an arrangement where the tops of the sticks were slightly higher than the one before but failed to keep the bottom line straight (Piaget, 1952).

As the pre-operational stage develops, the child is generally able to produce an arrangement where each stick is longer than the one before it. But the child does not build this arrangement without difficulty. Sometimes he begins by ignoring the bottoms of the sticks, as the early pre-operational child does. Other times he makes errors with the placement of sticks. The child produces many arrangements using trial and error, lacking an overall plan. When a new set of sticks was added (each of these new sticks could fit in between a pair of sticks in the 1st series) and the children were asked to place the new set into the 1st series, they had great difficulty with this and many failed to solve it. One factor appears to be that the children perceive the original series as a whole and find it hard to break up the series into smaller units. The child produces many arrangements using trial and error, lacking an overall guiding principle.

After about the age of 7 years, the child is successful in all of the seriation tasks. When asked to construct a single ordering of sticks differing in size, the child does so quite easily. The ordering is guided by an overall plan. The child usually begins with the smallest (or sometimes, with the largest), then the next smallest, and so forth, in sequence until the ordering is complete. When asked to place the additional set of sticks in their proper positions within the series already constructed, the child does so with almost no errors.

iii. Causality

Causality is an awareness of cause and effect relationships, which begins to develop in the sensori-motor stage. At birth, the child believes that his own actions are the source of all causality. This is due to the egocentric nature of a child in this stage. Between the ages of 8-12 months, the child becomes aware that objects around him can cause activity. This concept of causality begins to develop during the second half of the sensori-motor stage. A child in the early concrete operational stage begins to link a certain cause with an effect i.e. 'this goes with that', however thinks in terms of single causes only. A child in the late concrete operational stage has the ability to not only describe cause and effect relationships e.g. 'as this goes up that goes down', but can also consider multiple causes for an effect. The schema of causality becomes fully developed in the formal operational stage when an explanation for a relationship can be described, offering a 'formal model' for why a cause has an effect (Adey, 2008)

iv. Conservation

Conservation is the ability to realise that some amount, (either number, mass, weight or volume) remains the same despite changes in physical arrangement. Piaget investigated conservation in a number of different situations. In the conservation of number, he was not concerned with computational skills, which can be memorized without understanding. Piaget states that for mature understanding of number, memorization is not sufficient and a child must master certain basic ideas such as one to one conservation (Ginsburg & Opper, 1987). In this situation, two rows of equal number of coins are laid out so that both rows are of equal length. The child is asked whether the two rows contain equal number of coins. The second row is then elongated so that there is more space between each coin and the same question is put to the students. In this experiment, a child in the early pre-operational stage fails this task as they cannot comprehend reversibility or follow transformations. They solely focus on the length of each row of coins and answer that the second row contains more coins, as it is longer. The answers from a child in the late pre-operational stage often vary. Sometimes he states that the longer row has more coins because it is longer and sometimes he answers that the shorter row has more coins because it is 'denser'. A child in this stage focuses on one variable of the problem rather than both at the same time. This is known as centration and is a feature of the pre-operational child.

A child in the concrete operational stage is fully able to conserve number. Unlike the pre-operational child, he has the ability to focus his attention on both variables at the same time, which is known as decentration. The child is also aware of compensation between the two variables i.e. as the length of the row increases, the 'density' of the coins decreases. The pre-operational child cannot comprehend compensation, as it is a form of reversibility and cannot, therefore, comprehend conservation of number.

The experiments for the conservation of quantity, mass, weight and volume are similar to that of number. They involve two phases; the first where the child must recognise that the amounts, either liquid, mass, weight or volume, are equal, and a second phase where the child must judge whether the amounts are still equal, despite changes in physical appearance. Most children are successful in the first phase by about 4 years of age. Piaget also found that once a child masters conservation in one area, say number, he is unable to immediately apply his general knowledge to other areas for example, volume. A child masters conservation of the different areas in a sequence starting with conservation of number at age 5 or 6, substance, area and liquid at age 7 or 8, weight at age 9 or 10 and does not comprehend the conservation of volume until about 11 or 12 years of age (Inhelder & Piaget, 1958).

v. Combinatorial Thought

Combinatorial reasoning describes the ability to solve permutation and combination problems. Generally speaking, permutation and combination problems are concerned with the question of how many different ways an operation can be performed on a certain set of objects. To solve combination problems, one must be able to imagine all possible hypothetical arrangements of a set of objects. While the ability to understand combinations begins to develop in the concrete operational stage, it is not fully developed until the formal-operational stage. A child is presented with 5 jars containing colourless liquids. Three of the jars are mixed together to produce a yellow colour. The child is showed the yellow liquid but is not shown how it was made. When asked to make the yellow liquid for themselves, a concrete operational child will test combinations of 2 jars at a time. When this fails, typically a child in this stage will then test a combination of all 5 jars. However, a child in the formal operational stage will systematically test all possible combinations of 2 and 3 jars until the solution is reached. The concrete operational child's exploration is systematic up to a point but they do not have the ability to see all possible combinations (Inhelder & Piaget, 1958).

b) Schemata of formal operations

The most sophisticated stage of cognitive development is that of formal operational thought. In this stage schemata reach maturity at about 15-16 years. The main reasoning patterns of formal operations are shown in Figure 2.2. Each reasoning pattern is now explained below.

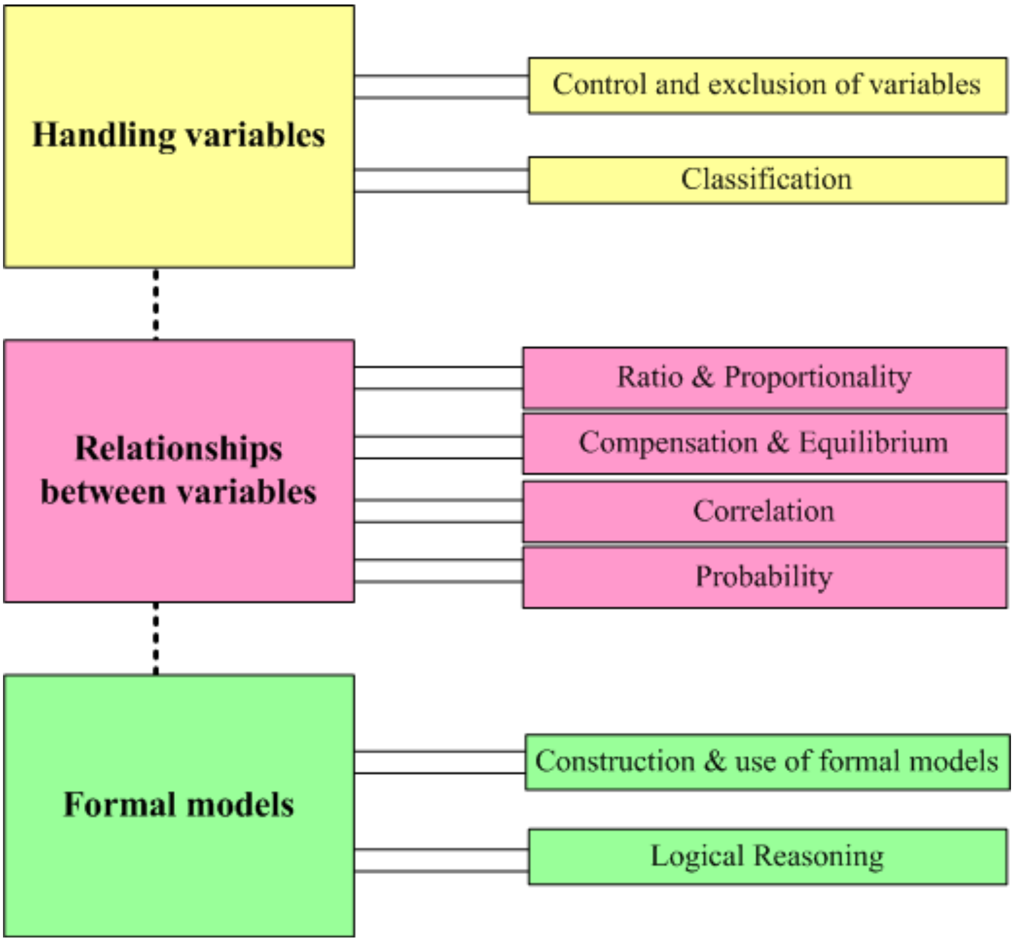

Figure 2.2: Schemata of formal operations (Taken from McCormack, 2009)

i. Handling Variables

The ability to handle variables requires an understanding of the schema of classification and the control of variables. Handling variables is particularly important in science and other domains. In a simple experiment, all but one variable must be kept constant so that any resulting change can be attributed to the variable under investigation. In a problem involving a pendulum (Adey & Shayer, 1994), the length of the pendulum, weight of the bob and the force of the push are all factors, which may contribute to the rate of the swing. However, only 30% of 15 year olds could provide the correct answer to the following question (Shayer & Wylam, 1978):

> *Given a SHORT pendulum with a HEAVY weight and a GENTLE push, what other arrangements would you use to test for the effect of length on the rate of swing?*

Students commonly change more than one variable, or change two variables and attribute any effect to both variables. This problem places a high demand on working memory space, as students must hold three independent variables in mind and consider the possible effects on one dependent variable. This level of thinking is not readily available to students younger than about 12 years (Adey & Shayer, 1994)

ii. Relationships between variables

The extent to which variables are related can be relatively straightforward, but some relationships are more complex and quantitative. The characteristics of these relationships are discussed under ratio and proportionality and compensation and equilibrium.

- Ratio and Proportionality

Ratio describes a constant multiplicative relationship between two variables. It illustrates the number of times one value contains or is contained in another. Ratio has the mathematical formula $y=mx$. As x increases so must y to keep the ratio. A child in the concrete operational stage can comprehend ratios involving simple whole numbers but do not fully understand problems involving ratios until the formal operational stage (Inhelder & Piaget, 1958).

Proportionality is a closely related concept and involves the comparison of two ratios. An example of proportionality involves comparing 5:25 and 9:45 and understanding that they are equivalent ratios. In information processing terms, handling proportionality involves the mental manipulation of four variables independently. Only a student in the formal operational stage can comprehend such a task.

- Compensation and Equilibrium

Compensation describes a relationship between two variables with a mathematical equation of $yx=m$. As one variable increases, the other must decrease to keep m constant. A concrete operational child is capable of comprehending additive or qualitative compensation. In the example discussed previously, where a row of coins is elongated, a concrete operational child understands that as the length of the row of coins increases, the 'density' decreases. The ability to comprehend multiplicative compensation comes long after the additive form. It requires formal operations to express a compensation relationship mathematically and use this expression to calculate, for example, exactly how far out a 25N force must be moved on a lever to exert the same force as a 75N force closer to the fulcrum (Adey & Shayer, 1994).

Equilibrium is mathematically expressed as $ab=cd$, and involves equating two compensations. A simple example is a ruler, balanced on a fulcrum, with weights hung on either end. A concrete operational child has the ability to substitute three values into an equation such as

$$m_1 \times d_1 = m_2 \times d_2$$

to find a fourth unknown. However, the ability to understand that if m_1 is increased then m_2 can also be increased to restore the balance requires formal operational thought. If $m_1 = m_2$, the task is at a concrete level as the same is done to both m_1 and m_2. However if $m_1 \neq m_2$, proportionality has to be used to see what to do to m_2 to restore the balance and therefore the task is at a formal operational level (Adey & Shayer, 1994).

- Correlation

Correlation is the statistical measurement of the relationship between two variables. When dealing with living things there is naturally a great deal of variation. It is not always possible to arrange a relationship into a mathematical formula. To determine whether or not there is a correlation between two variables one must consider all possibilities. For example, to determine whether using a certain fertiliser in the soil will increase carrot size, all four possibilities must be considered i.e. carrots which have been treated and are small, carrots that have been treated and are large, untreated carrots that are small and untreated carrots that are large.

Table 2.2: A 2x2 treatments and effects table.

	With Treatment		Without Treatment	
No effect	A	4	B	6
Positive effect	C	8	D	7

To determine whether or not there has been an effect, one must compare the results, which indicate that the treatment has had an effect (cells B and C) with the results, which suggest that the treatment has had no effect (cells A and D). In this instance, a 14:11 ratio is established. Although there appears to be a correlation between treatment and effect it is a weak correlation as the results could also be due to chance. The ability to comprehend correlations is a feature of formal operational thought alone. Students in the early formal operational stage tend to view correlations as simple probability and do not fully comprehend the concept until the late formal stage (Adey & Shayer, 1994)

- Probability

According to Piaget, the development of the schema of probability depends on the development of formal operations in general and the development of the proportionality schema in particular (Brainerd, 1978). All events can be classified into two broad categories *(a)* events that absolutely *must* happen because they are governed by natural law and *(b)* thing that *should* happen because they are not governed by any natural law. If a rock is dropped from the top of a building, it *must* fall to the ground due to the law of gravity. However, if a coin is flipped 10 times, approximately 5 heads *should* be obtained. Dividing events into these two classes is the heart of the probability schema. According to Piaget, the development of the schema of probability is divided into three main stages, which correspond to the pre-operational, concrete operational and formal operational levels. Children in the pre-operational stage fail to grasp the difference between events governed by natural law and events governed by chance. They tend to think that the chance event may actually be governed by natural laws. Concrete operational children understand that there are certain situations in which they cannot figure out a rule to allow them to make predictions but when considering purely chance occurrences, concrete operational children have great difficulty distinguishing between events that are more or less likely to happen. For example, when considering flipping a coin 100 times, they may not realise that an outcome of 50 heads and 50 tails is much more likely than 75 heads to 25 tails. Concrete operational children cannot comprehend the frequency principles that govern systems of chance events. These principles are not discovered until the formal operational stage and coincide with the development of the schema of proportionality.

(iii) Formal models

- Construction of formal models

A model is a representation of something else. A child in the concrete operational stage can construct simple models based on concrete objects. However, a formal model is a working model in which the 'moving parts' are abstract entities. The kinetic model of matter is an example of a formal model since the particles cannot be seen, only imagined. This model is useful as it explains the behaviour of particles in all three states of matter. It can also be used to predict the behaviour of matter and in some sense represents reality. Models can be used in many areas including sociology, weather forecasting and economics. They can be used to make predictions and to understand behaviour. Once a model has been represented as an algorithm, it only requires concrete operational thought by entering values for certain variables. However, formal operational thought is required when the predictions fail or when the significance of the prediction in relation to the evidence needs to be interpreted (Adey & Shayer, 1994).

- Logical Reasoning

Logical reasoning describes the ability to analyse combinatorial relations present in information given. Adey and Shayer (1994) highlight a test of logical reasoning taken from Bond's test of logical thinking (BLOT) (Bond, 1976). The BLOT is a paper and pencil test developed as an alternative to Piaget and Inhelder's interview technique. The following example illustrates the logical operation of implication.

> *A prospector has found that some rich metals are sometimes found together. In his life he has sometimes found gold and silver together, sometimes he has found silver by itself, every other time he has found neither silver nor gold. Which of the following rules has been true for the prospector?*
>
> 1. *Gold and silver are found together, never apart.*
> 2. *If he found silver then he found gold with it*
> 3. *If he found gold then he found silver with it*
> 4. *If he found gold then he did not find silver*

Performance on the BLOT test shows a high correlation with Piagetian tests derived from *The Growth of Logical Thinking* (Inhelder & Piaget, 1958). Table 2.3 highlights the types of thinking characteristic of each stage of development.

Table 2.1: Development of the schemata from pre-operations to formal operations. Adapted from (Adey, 2008) and (Adey *et al.* 2003)

Schema	**Piagetian Level**			
	1: Pre-operational	**2A: Early Concrete Operations**	**2B: Mature Concrete Operations**	**3: Formal Operations**
Classification	Cannot put a mixture of objects into groups which are alike. More inclined to make patterns.	Group objects according to one main characteristic (e.g. size or shape) and then two-way (Large squares, small triangles)	Understand hierarchical classification, Sub–groups within large groups (ducks are birds, are vertebrates, are animals)	Use classifications spontaneously to search for patterns in data or characteristics.
Seriation	Unable to put more than 3 or 4 object in order, even given criterion (e.g. Length).	Can order 10+ objects, given a single salient dimension.	See seriation as a natural way to deal with objects or data. Can relate to series to establish relationship (e.g. the greater the mass, the longer the spring) with some quantification.	See point in seeking explanation for order established empirically
Causality	Interprets phenomena egocentrically, in terms of self	Associate reasoning ('this goes with that'); thinks in terms of single causes only.	A reason involves describing a relationship 'As this goes up, that goes down'; can imagine two causes for an effect.	Now an *explanation* for a relationship can be described, offering a' formal model' for why a cause has an effect.

Conservation	No conservation: Two equal rows of coins are seen as different numbers when one is stretched out	Conserve Number. Simple liquid volume conservation, But volume of water displaced not seen as equal to volume of object put in the water.	Now can conserve displaced volume, but dissolved solids (e.g. Salt) may be thought of as having disappeared.	All Conservations; Can measure the volume of irregular object by displacement.
Spatial Perception	Egocentric. Cannot imagine view from anyone else's position.	See the idea of mentally seeing a view from another position, but still make many detailed mistakes.	Able to select accurately a picture depicting a scene from a different viewpoint.	
Combinatorial Thought			Will test a number of combinations but unable to see all possible combinations.	Able to generate all possible combinations.
Control of Variables		Reject a proposed experiment that is manifestly unfair but also interpret ' fair' as compensation. Does not separate variables so cannot comprehend need to ' control' any.	Still often vary more than one factor at a time.	Can see the need to vary one factor at a time and can suggest experimental tests to control variables.

Ratio/ Proportionality		Can double or halve the quantity of two ratio's	Can scale up/down using simple whole numbers	Can understand proportionality including density
Compensation/ Equilibrium			Can comprehend single relationships such as force but not compound variables	Can comprehend equilibrium where there are two independent variables related two each other provided the ratios are simple whole numbers
Probability			Understand that there is a 50/50 chance of getting a heads when flipping a coin	Fully understand probability and can express chance as a fraction
Correlations				Begins to look at the ratio of confirming to disconfirming cases, but tends to look only at the probability of two of the four cases
Formal Models			Simple modelling based on seriation, causality and classification	Can devise formal models for abstract ideas. Can understand combinations, therefore capable of logical thought.

2.1.2 Criticisms of Piaget

Piaget's work offers a rich and diverse theory of cognitive development. It includes a broad spectrum of developments in children's thinking from infancy to adolescence. Some criticisms of his work include experimental issues, cross-cultural issues, a reliance on language and objects, and a disregard for important elements in development such as social, emotional and economic differences (Cohen, 1983). Flavell (1963) noted that Piaget's work never received the attention or recognition it deserved and, according to Cohen (1983) this lack of criticism from equals "narrowed him" (p.81). He believed that if Piaget had been called upon to defend his experiments and ideas, he might have modified them more. However, Lourenço and Machado (1996) propose that some criticisms of Piaget are derived from widespread misinterpretation of his theories and ideas. Three main points of criticism of Piaget's work, which are relevant to this study, are discussed below.

(i) Piaget underestimated the competencies of young children

One major criticism of Piaget's work is that he underestimated the competencies of young children, especially those of the pre-operational child (Lourenço & Machado, 1996). It has been suggested that the language used in Piagetian tasks is too difficult, and psychologists wonder if the children understand what they are being asked (Cohen, 1983). Over the years, the tasks have been simplified in terms of language, instructions, scoring criteria and other procedural details. A number of studies revealed that 5- to 6-year old children are capable of competencies that Piaget considered examples of concrete operational thought. These include numeric reasoning (Gelman & Gallistel, 1978), conservation (McGarrigle & Donaldson, 1974) and class inclusion (Markman, 1973).

(ii) Ignored individual differences/Misjudged age norms

Piaget has been criticised for ignoring important, vital, elements in development such as social, personality and economic differences (Cohen, 1983). This has led to criticism of his proposed correlation between chronological age and operational level. Shayer *et al*. (1976) and Shayer & Wylam (1978) were able to establish norms and distributions for these stages in whole populations. Their study demonstrated that the range of stages of thinking which occurred in a representative sample of children was extremely wide. Typically, a school group, with an average age of 12 years, contained students who reason as average 8 year olds and others whose thinking is similar to the top third of 16 year olds. The results also revealed that only about 30 per cent of students at the ages of 14 to 15 years demonstrated formal operational thinking. However, Lourenço & Machado (1996) dispute this conclusion, as they believe it is based on another widespread misinterpretation of Piaget's theory. They argue that the primary concern of Piagetian theory was the sequence of transformations rather than age of acquisition of competencies. According to Lourenço & Machado (1996), critics "often assume that Piaget considered age a criterion of developmental level, whereas for Piaget the key element was the sequence, not the age, of cognitive transformations" (p.9). They maintain that in Piagetian theory, age is an indicator, not a measure, of cognitive development.

(iii) Issues with stage theory

Piaget's stage theory assumes a series of distinct developmental stages, each marked by the ability to perform certain logical operations and the inability to perform others (Flavell, 1977). Each stage is represented by a certain set of characteristics and that once a child moves into that stage; all actions are bound together by one underlying level of logic. Many researchers have questioned whether cognitive development is as stage-like as Piaget assumed (Flavell, 1977; Gelman *et al.,* 1982; Siegler, 1998). According to Siegler (1998), stage models imply that cognitive thinking changes qualitatively from one stage to another. A child in a certain stage applies the same reasoning across a diverse range of problems and cannot employ types of thinking much more advanced than those characterised by their current stage. One criticism of this theory is the apparent "abruptness" at which children move from one stage to another according to Piaget (Flavell, 1977; Siegler, 1998). Flavell (1977) argues that cognitive development is a continuous and gradual progression. A child does not suddenly enter a developmental stage and be capable of the level of thought characterised by that stage, followed by several years of relatively no cognitive growth. Research suggests that cognitive developments appear to proceed slowly and gradually rather than abruptly. A child can take many years to perfect, generalize, and solidify their grasp of a certain concept and therefore, the stage itself, and not the transition to it, becomes the period of continuous growth and change (Flavell, 1977).

In summary, Piaget's theory has been criticised for many reasons, including underestimating the abilities of young children, overestimating those of older children, ignoring individual difference and for being too "stage-like". However, even with all of its apparent shortcomings, Piaget's theory offers key ideas on how children think and learn at different periods of development. It has given researchers an insight into how children process information, adapt to their environment and describes important acquisitions over a significant period of time. Piaget's theory has been a suitable platform for other researchers to learn more about how children think (Siegler, 1998).

2.2 Vygotsky's social constructivist theory

According to Vygotsky, cognitive development is largely a social process and that language plays an essential role in the organization of 'higher psychological functions' (Vygotsky, 1978). He maintained that language and action are equally important in development, and that they are components of the same complex psychological function. Vygotsky believed that the most significant moment in intellectual development occurred "when speech and practical activity, two previously completely independent lines of development, converge" (1978, p.24). This begins with goal directed, egocentric or private speech, which a child uses to organize their thinking. The child then learns to internalize this speech and becomes increasingly able to organise their thought.

Vygotsky's work on cognition began in part with his dissatisfaction with the use of psychometric tests to predict children's ability to make progress in school learning, in particular with reading. He was dissatisfied with what he described as 'static' testing, where the test items could be impartial and a focus on speed meant that only the skills and schemata readily available to the child were being investigated. Vygotsky developed what he described as 'dynamic' testing to gain a deeper insight into the child's potential to learn, which involves individual interviews between the child and a psychologist. The psychologist can obtain a measure of the child's potential to learn by comparing the child's unassisted responses, with their final responses following a discussion about possible solutions to the test item. Vygotsky (1978) showed quantitatively that the information derived from this mode of testing lead to better predictions of children's progress in school learning over the next two years than the previously used 'static' tests did (Adey & Shayer, 1994).

Vygotsky (1978) proposed that to learn and develop, children should work within their *Zone of Proximal Development* (ZPD), which he described as:

> *The distance between the actual and developmental level, as determined by independent problem solving, and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers* (Vygotsky, 1978 p.86)

He believed that with help, a child could perform tasks which would normally be considered out of their mental capabilities, and that "what children can do with the assistance of others might be in some sense even more indicative of their mental development than what they can do alone," (Vygotsky, 1978 p.85). He proposed that working within the ZPD is essential for development. According to Vygotsky, the ZPD should not be viewed as a simple internal function of the child. Through social interactions, we move towards more individualized thinking. Vygotsky's theory is limited as he never fully described the internal process that resulted in cognitive development. However, his work highlights the importance of children as social learners, which has had a significant impact on education (Goswami 2008).

2.3 Information processing theories of development

Information processing theories of development differ to those of Piaget and Vygotsky. Their basic assumption is that thinking *is* information processing and that change in thinking is continuous. Structurally, information processing comprises of three components: sensory memory, long-term memory and working memory (Siegler, 1998). Sensory memory involves converting external stimuli from the outside world into electrochemical signals, while long-term memory stores large amounts of information for an unlimited amount of time. Working memory is "where the thinking occurs: constructing new strategies, computing solutions to arithmetic problems, comprehending what we read, and so on." (Siegler, 1998 p.67). The operation of the working memory is limited by its capacity, which is the number of 'chunks' it can process at a given time. This development of the working memory capacity occurs slowly with age and is constrained by the central nervous system. Information processing theories differ in themselves. Theorists such as Case (1985), and Pascual-Leone (1976) link the development as described by Piaget to the growth in working memory capacity, with increasing capacity allowing for increasing numbers of 'chunks' of information to be processed in parallel. However, according to Adey (2004), an increase in working memory capacity can only explain a limited range of observations of the mind and does not account for specialized abilities within specific domains (Anderson, 1992; Carroll, 1993).

Researchers such as Anderson (1992), Carroll (1993) and Demetriou *et a*l. (1993) believe that the mind is governed by some general processing ability or "central processor". This central processor is supported by abilities that are specialized within domains. Evidence for the existence of a general processing ability includes work by Anderson (2001), which shows that there is always a significant correlation between higher-level thinking across all domains (Adey, 2006). In the model proposed by Demetriou *et al*. (1993), the specialised abilities develop somewhat independently, but are constrained by the development of the central processor. The growth of the central processor is linked to an increase in both the capacity and efficiency of working memory.

According to Adey *et al*. (2007), the central processor is plastic and is therefore open to stimulation or stunting. This notion of plasticity is also a feature of Piaget and Vygotsky's theories of development, in that the mind advances in responses to challenge. Educators have the power to raise their students' cognitive ability through cognitive stimulation, and in turn raise all of their academic performances. Adey *et al*. (2007) suggest that, to advance students' general processing abilities, learning activities should:

- generate cognitive stimulation,
- be collaborative,
- continually make students aware of what can be taken from domain specific learning and generalized to other areas and,
- connected to past learning experiences.

2.4 Methods to accelerate cognitive development

A number of programmes have been developed which aim to enhance and promote cognitive development. These programmes incorporate key features such as creating challenge, mediated learning and active reflection. These programmes can be classified as either context-independent or context-delivered (Adey *et al*., 2007). Context-independent approaches, such as Feuerstein's Instrumental Enrichment programme (Feuerstein *et al.,* 1980), aim to improve general thinking skills and are delivered in special thinking lessons. Context-delivered approaches, such as Philosophy for Children (Lipman *et al*., 1980) and CASE, aim to enhance thinking skills in a domain specific way, and involve intervention programmes delivered within the context of a school subject. Two of the main programmes i.e. Instrumental Enrichment and Philosophy for Children, are summarized below.

- **Instrumental Enrichment (IE)**

One of the most well known context- independent interventions is Feuerstein's Instrumental Enrichment programme (Feuerstein *et al.,* 1980). Instrumental Enrichment is centred on the notion that intelligence is not fixed, and that we learn through mediated learning. The two-year programme is designed to increase children's thinking abilities through cognitive stimulating tasks. The programme consists of 14 progressively more demanding activities focusing on the schemata as described by Piaget and Inhelder (1958). The activities are facilitated through peer-mediated learning, which is a Vygotskian concept. It is through mediation with a more expert individual that students are able to be more independent thinkers and learners.

The successful intervention was initially designed for adolescents from 12 to 14 years of age, who were deprived of the Mediated Learning Experiences (MLE) considered necessary for cognitive development. IE has a metacognitive focus on 'thinking about thinking' and 'learning about learning' rather than specific subject matter. The activities help the students develop strategies and working habits that they can apply to problem solving situations and generalise rules and principles, which can be transferred to a wide range of curricular and extra-curricular domains and contexts. At the end of the two year IE course, Feuerstein's students had shown modest gains in terms of increased IQ, when compared with a control group and they also demonstrated an ability to transfer learning from one situation to another (Shayer & Beasley, 1987).

However, two years after the end of the intervention, the most noticeable results were observed. On entry to the Israeli army, the intervention group were found to have an average general intelligence equivalent to that of the general population, despite being three years behind prior to starting the intervention. Feuerstein's IE programme has proved to be beneficial for a wide spectrum of children and adolescents in different countries. For example, Shayer and Beasley (1987) implemented IE in one class in a Special School in England and reported effect sizes of 1.22 on Piagetian tests. Adey *et al*. (2007) suggested that the IE is not more widely used in schools as the developers will only release the published materials as part of a packing including an expensive teacher training programme. Also, as the programme is context-independent, it requires teachers to find extra time in the school day to cover the activities.

- **Philosophy for Children**

'Philosophy for Children' (Lipman *et al.,* 1980) is a context-delivered intervention that aims to promote higher order thinking and improve students reasoning abilities through the English or social studies curricula. The activities present students with a moral, social or intellectual dilemma, which is resolved through communities of inquiry. Communities of inquiry are encouraged so that students can build on each other's thinking by contributing counter arguments and examples. Lipman (1998) considers communities of practice to generate higher order thinking and sounder reasoning, understanding and judgments.

The programme was initially designed for students aged between 10-12 years, but has expanded to include programmes for children ranging from 6-16 years. The materials consist of a series of progressively difficult 'novels', which aim to create debate amongst students, which must be resolved through reasoning. Students are encouraged to externalise their reasoning and in doing so become aware of their own thinking strategies. The teacher provides open-ended questions in a supportive, safe environment. The Philosophy for Children programme has been shown to result in consistent positive effects on a wide range of outcome measures and ages. In a review of 10 experimentally rigorous studies evaluating the effects of the Philosophy for Children programme, Trickey and Topping (2004) report positive effects in relation to reading, reasoning and cognitive abilities, with a mean effect size of 0.43 and very little variance. The Philosophy for Children programme has evolved over time and is currently used in a wide range of contexts and countries including the UK, the USA and Canada (Trickey & Topping, 2004).

2.5 Cognitive Acceleration through Science Education

In the 1970's, Shayer and Wylam used the Science Reasoning Tasks (SRT's) developed by the CSMS (Concepts in Secondary Mathematics and Science) team (NFER, 1979) to establish age norms and distributions for the developmental stages as described by Piaget (Shayer & Wylam, 1978). They highlighted that the range of stages in a given sample was extremely wide, and that there was a mismatch between curriculum demands and student cognitive abilities. To resolve this disparity, the team at King's College, led by Adey, Shayer and Yates, developed a set of activities aiming to accelerate students' progression through the developmental stages as described by Piaget. Each CASE activity is framed around the most prominent features of cognitive psychology, such as generating challenge, mediated learning and metacognitive thinking. The schemata, as described by Piaget and Inhelder (1958) provide the context for which the activities are set.

The initial CASE programme was a 2-year intervention, which aimed to increase the percentage of 11- 14 year olds (Years 7 and 8) at the formal operational level in the United Kingdom. A period of 2 years was selected based on the work of Feurerstein, which reported that students who received two years of the Instrumental Enrichment (IE) intervention performed better than those who only had one year (Feuerstein *et al.,* 1980). In terms of ability, the target population for the CASE programme was the middle 80% to 90% of students. Adey (1999b) felt it impractical to include within the target population either the exceptionally able students, who would already be using formal operations by the age of 11 years, or the students with serious learning difficulties, who at 11 might still be at the pre-operational level.

The materials of the CASE project, called *Thinking Science!,* were first published in 1989 and can be seen in Table 2.4 (Adey *et al.,* 1989). The original materials contained 31 lessons, which averages at one lesson implemented per fortnight. The activities are embedded within the science domain as the schemata described by Piaget and Inhelder are "easily seen as underpinning all higher level school science" (Adey, 2004 pg. 298). Each lesson focuses on one of the schema as shown in Table 2.4. When a schema is met for the first time it is quite simple but becomes increasing complex as the programme progresses. For this reason, it is advised that the lessons are taught sequentially.

Table 2.1: Thinking Science activities and their associated schemata (McCormack, 2009)

Lesson Number	*Thinking Science* Activity	Variables	Proportionality	Probability	Compensation	Correlation	Equilibrium	Classification	Formal Models
1	What Varies?	✓							
2	Two Variables	✓							
3	The 'fair' Test	✓							
4	What sort of Relationship?	✓							
5	Roller Ball	✓							
6	Gears and Ratios		✓						
7a	Bean Growth 1			✓					
7b	Bean Growth 2			✓					
8	The Wheelbarrow		✓						
9	Trunks and Twigs				✓				
10	The Balance Beam				✓				
11	Current, Length, Thickness				✓				
12	Voltage, amps and Watts				✓				
13	Spinning coins			✓					
14	Combinations	✓							
15	Tea Tasting			✓					
16	Interaction	✓							
17	The Behaviour of Woodlice					✓			
18	Treatment 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	Uphill and Down Dale						✓		
29	Equilibrium in the balance						✓		
30	Divers	✓							

2.5.1 Pillars of the CASE programme

Each CASE activity has 5 main phases or 'pillars', which draw on the theories of Piaget and Vygotsky and on features of Feuerstein's IE programme (Feuerstein *et al.,* 1980). Shayer (1997) describes how both Piaget's and Vygotsky's theories are both necessary for the successful implementation of the CASE programme. The 'framing of the tasks themselves' are derived from Piagetian theory while the 'hardware' and the 'conduct' of the lessons are drawn from Vygotskian approaches. The main pillars of the cognitive acceleration methodology and their theoretical influences are summarised in Table 2.5.

Table 2.2: Influence of Piaget, Vygotsky and Feurerstein on the development of CASE (Adey & Shayer, 1994)

	Piaget	Vygotsky/ Feuerstein
Schemata of Formal Operations	✓	
Concrete Preparation	✓	✓
Cognitive Conflict	✓	
Metacognition		✓
Bridging		✓
Construction	✓	✓

Each pillar is discussed in more detail below.

(i) Concrete preparation

Concrete preparation is the beginning of the lesson where the framework for the problem is set. Students become familiar with new apparatus and vocabulary so that their performance in the task is not hindered by these factors. Difficulties encountered by a child should be on an intellectual rather than a practical level. Prior knowledge on the task is established as "a problem without context or meaning is not worthy of attention" (Adey & Shayer, 1994).

(ii) Cognitive conflict

This phase of the lesson relies on the Piagetian idea that it is the mind's response to challenge which drives cognitive development (Woolfolk *et al.,* 2008). The aim of the CASE activities is to create a cognitive conflict situation that is sufficiently challenging to shift the student to a state of disequilibrium. Cognitive acceleration activities are designed to be just beyond the current capabilities of the student in order to induce conflict and result in a change in the student's current schemata. The Zone of Proximal Development (ZPD) as described by Vygotsky defines the range within which the cognitive conflict can be productive.

An example of cognitive conflict can be seen in lesson 27 of the *Thinking Science* programme. The lesson titled '*Floating and Sinking'*, deals with the concept of density by focusing on the underlying schema of compound variables. In the cognitive conflict part of the lesson, students are presented with two sets of concealed jars. The first set of five jars, labelled A-E, are all of the same size but vary in mass from 400g to 1200g. The second set of six jars are labelled 1-6 and are of varying sizes but have the same mass. Jars A and 6 are identical. The two sets of jars can be seen in Figure 2.3 [taken from (McCormack, 2009)]. Students are asked to weigh each jar in the first set and record whether it floats or sinks. The only variable changing in this set of jars is the mass. From this investigation, students can create a model that 'heavy things sink and light things float'. The same procedure is repeated for the second set of jars and the students create a model that 'small things sink and large things float'.

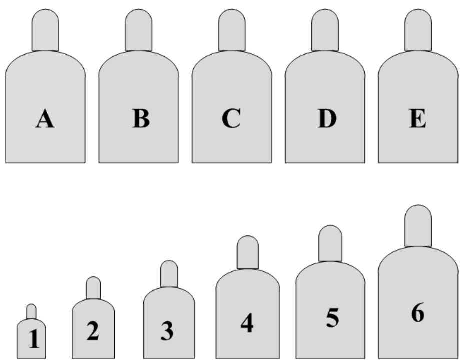

Figure 2.1: Lesson 27; Floating and Sinking, Density jars A-E and 1-6 (McCormack, 2009)

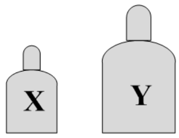

Figure 2.2: Lesson 27; Floating and Sinking, Density jars X and Y (McCormack, 2009)

At this point, jar X, which can be seen in Figure 2.4 is produced. Jar X is the same size as jar 3 and weighs the same as jar C. Students are asked to predict whether the jar will float or sink based on their knowledge of jars 3 and C. The models established would lead to the conclusion that jar X will float, but when it is placed in water, it sinks. Here a cognitive conflict arises between the students' previous experience and the information before them. Students at this point are puzzled and seek reasoning for this surprising result. A more complex formal operational reasoning model is necessary, namely that of the compound variable, density. The same procedure is carried out with jar Y, which is the same size as jar 5 and the same mass as jar B. Not all students will grasp the concept of density from this one conflict experience but together with the other pillars of the lesson they should be able to develop some general ideas on compound variables.

(iii) Social construction

Social construction is the phase in the lesson where equilibrium is restored following cognitive conflict. Resolution of the cognitive conflict occurs through mediation with a teacher or peer, as described by Vygotsky (1978). These two pillars feed off each other, as cognitive conflict should generate 'good talk' between students, and between students and the teacher, which in turn generates further cognitive conflict. Two students working together on a complex problem can challenge and enhance one another's thinking, which provides new meaning (Adey, 1999a). CASE activities encourage students to describe and explain their ideas and to engage in constructive dialogue with peers while attempting to solve a problem. The cognitive conflict has to be efficiently managed by a teacher so that the students can construct the reasoning patterns for themselves and resolve the conflict. Encouraging meaningful dialogue is considered an important feature of an intervention aiming to increase cognitive development, and is an element of both Feuerstein's Instrumental Enrichment and Lipman's Philosophy for Children programmes (Adey & Shayer, 2011). Adey (1999) considers cognitive conflict and social construction as two sides of the one coin. Meaningful dialogue is necessary to resolve cognitive conflict and that this meaningful dialogue can only be constructed through challenging situations.

(iv) Metacognition

Metacognition describes being conscious of one's own thinking and reflecting on one's own actions (Flavell, 1979). According to Donaldson (1978), children's reflection on problems and review of possible strategies before acting are important aspects of cognitive development. She states that, "If the child is going to control and direct his own thinking, in the kind of way we have been considering, he must become conscious of it" (Donaldson, 1978 p.94). Metacognitive thinking can be distinguished from other kinds of thought in that it involves reflection on thinking, strategies employed and how ones concepts have changed, rather than merely thinking about what was done. In the metacognition phase of the CASE activity, the students are encouraged to make the thinking they engaged in explicit so that it can be employed in another context (Adey, 2004). Metacognition is also a feature of Feuerstein's IE (1980) and Lipman's Philosophy for Children (1980) programmes where adults, acting as mediators of learning, encourage metacognitive thinking in their students. In practice, a teacher can ask pupils to reflect on their thinking and learning, discuss any difficulties they encountered and how their thinking has changed. As Larkin (2008) describes: 'it is only after one has solved a problem that one can learn most efficiently how one should have solved it' (p.30). Piaget described this consciousness of one's own thinking as a feature of the formal operational child, however, Adey and Shayer (1994) see metacognition as available 'in some intellectually honest way' to any child who has developed a theory of mind, which generally occurs at about 4 years of age. Larkin (2006) showed that children as young as 5 years old exhibited metacognitive thinking during CASE lessons, and that with continued practice and encouragement, it could become a feature of their collaborative work. Georghiades argues that, '*the question at issue is not whether children have the potential to engage in metacognitive activities; rather, it is one of finding the right ways and the right activities for initiating and enhancing such activity'* (2004a, p. 370).

(v) Bridging

The thinking abilities developed during a CASE lesson are not limited to science and can be generalized for use in other contexts. The final pillar of CASE is to identify where similar thinking can be used and applied. Students are encouraged to think of other ways in which schemata developed within a lesson can be used in a more useful way. For example, following Activity 7A, 'Bean Growth 1', where the ideas of population variation and sampling variation are introduced at the concrete level, students are encouraged to apply this thinking to everyday life i.e. how representative are opinion polls? In this way, the thinking abilities developed within the lessons can be transferred and used in a wide range of settings (Adey & Shayer, 1994).

The integration of the five pillars provides the framework that all CASE activities are based upon. A lesson may have more than one episode of cognitive conflict, social construction and metacognition. The CASE methodology has been shown to have positive effects on students' academic achievement in a range of age levels and contexts, the results of which are discussed in the next section.

2.6 Effects of CASE on students' cognitive development and academic achievement

There have been three main phases of research into the CASE approach at second level in the UK. CASE I, the original project, which began in 1981 and lasted for 3 years, was a small-scale exploratory project in which 6 CASE lessons were developed and trialled in one school. CASE II was the main project, which used a quasi-experimental method with 10 intervention classes and 10 matched control classes in 7 schools. The CASE III experiment (1989-1991), focused mainly on the teaching skills involved with cognitive acceleration lessons and the development of a professional development programme. At primary level, lessons based on the CASE methodology, but aimed at 5-6 year old students, were implemented in 10 intervention schools and the students' cognitive gains compared against matched control students. Some of the significant results of the CASE intervention on students' cognitive development and academic gains will be discussed in this section.

2.6.1 The CASE II Project

The main aim of the CASE II project, which began in 1985, was the evaluation and development of activities and the testing of the programme to assess the effectiveness of the intervention on the students (Adey *et al.,* 2004). Of the 10 pairs of classes, four started CASE in Year 7 (designated the '11+' group) and six in Year 8 (the '12+' group). Intervention and control groups were given pre-tests of cognitive development before and post-tests immediately after the two-year intervention. One year later, all groups were administered a test on their science achievement and cognitive development. In 1989, those who started the intervention in Year 8 (namely the 12+ group) sat their GCSE examinations, followed by the 11+ group in 1990, who started the intervention in Year 7. The results of these tests are summarised in Table 2.6.

All test data was analysed in terms of mean Residualised Gain Scores (RGS), which is the gain made by the intervention group over that made by the control 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. In theory, the RGS of the non-intervention group should distribute around zero. If the RGS of the intervention group distributes around zero, it implies that the intervention had no effect on the parameter being measured. A positive RGS implies that the intervention has been beneficial; while a negative value indicates that the intervention group did not develop as much as the control group. Data was also analysed in terms of effect size. The effect size is the difference between the mean post-test scores of the experimental and control groups in units of standard deviation of the control group. An effect size of 0.35 is considered satisfactory while an effect size of 0.5 is considered good (Adey *et al*., 2004).

Some of the major features of the results of the CASE II project are highlighted below:

- The immediate effects of the CASE programme on cognitive development were rather limited at post-test. The 12+ boys were the only group who appeared to make significant gains over their comparable control group. However, the distribution of scores was bimodal with some students within the group making very large gains, while others made gains little more than the control group. Shayer (1999b) suggests that this pattern is attributed to small sample variation or a possible teacher effect.
- Girls appear to make greater gains if they start the intervention at an earlier age. The 11+ group made significantly larger gains in terms of academic achievement when compared with the 12+ group. The distribution scores for the 11+ girls group was also bimodal, with some students making sizable gains and while the gains of others were negligible.
- In spite of moderate immediate effects, there is a long-term effect of the intervention on students' academic achievement, with intervention groups outperforming control groups in GCSE results.
- Students who took part in the CASE intervention not only performed better in science and mathematics, but also received better grades in English. Adey and Shayer (1994) suggest that the *Thinking Science* lessons enhance students' linguistic development, so new linguistic skills can be more easily acquired. This also demonstrates that the thinking abilities developed during the *Thinking Science* lessons can be transferred to other areas not related to science.

Table 2.3: Mean gains and effect sizes for successive tests after completion of two-year CASE intervention, based on pre-cognitive tests (09/84) [(McCormack, 2009) adapted from (Shayer, 1999b)]

	Group (N)	Mean gain	Effect size (σ)
Cognitive post-test (07/87)	11+ boys (29)	-0.21	
	11+ girls (27)	0.08	
	12+ boys (65)	0.70**	0.75
	12+ girls (52)	0.03	
Science achievement (07/88)	11+ boys (37)	2.72	
	11+ girls (31)	7.02*	0.60
	12+ boys (41)	10.46**	0.72
	12+ girls (36)	4.18	
GCSE Science (1989)	12+ boys (48)	1.03**	0.96
	12+ girls (45)	0.19	
GCSE Maths (1989)	12+ boys (56)	0.55**	0.50
	12+ girls (54)	0.14	
GCSE English (1989)	12+ boys (56)	0.38*	0.32
	12+ girls (57)	0.41*	0.44
GCSE Science (1990)	11+ boys (35)	-0.23	
	11+ girls (29)	0.67*	0.67
GCSE Maths (1990)	11+ boys (33)	1.59	
	11+ girls (29)	0.94**	0.72
GCSE English (1990)	11+ boys (36)	0.26	
	11+ girls (27)	0.74*	0.69

*denotes significance at 95 percent confidence level
** denotes significance at 99 percent confidence level

One criticism of the CASE intervention is the use of Piagetian tests to assess the effect of an intervention, which was partially inspired by Piagetian psychology. Jones and Gott (1998) argue that improvement is inevitable on a task if students are taught such ideas. They reason that external examinations such as the GCSE and Key Stage 3 SATs are a more dependable measure of improvement. However, Shayer (1999b) argues that no apology is needed for using Piagetian tasks to measure student improvement as it "makes no sense to avoid using a measuring instrument because it is based on the same theory as the intervention" and that such a measuring tool should be first choice.

Overall results from the CASE II intervention indicate that the CASE groups made significant cognitive gains at the post-test, although this was largely concentrated at the 12+ boys and 11+ girls after a period of one year (Adey *et al.,* 2004). Shayer and Beasley (1987) suggest that better thinking abilities must have sufficient time to be applied to new learning before any gains in academic achievement are observed.

Whole school Implementation

A large-scale study was carried out between 1994 and 1999 of 11 schools whose whole science departments were trained in the use of CASE methods (Shayer, 1999b). Figure 2.5 shows the plot of the of the average science grade achieved versus the mean cognitive level at intake for each school. Each CASE school is represented by a letter on the graph. Cognitive levels are expressed as a percentile based on the results of the CSMS study carried out in 1978. The control schools were used to generate a regression line showing that a school's performance at GCSE is directly related to the general ability of its intake. The national average also falls on this line, which indicates that the control schools represent the national population. The results were analysed using the 'added-value' approach which compares the GCSE grades actually obtained by the school with those that would be expected from its mean intake level. The extent to which actual grades are higher than expected is a measure of the academic value added to the students by use of the CASE intervention. Any effect observed in results can be attributed to the CASE intervention, as it is the only systematic differences between the schools (Shayer, 1999b).

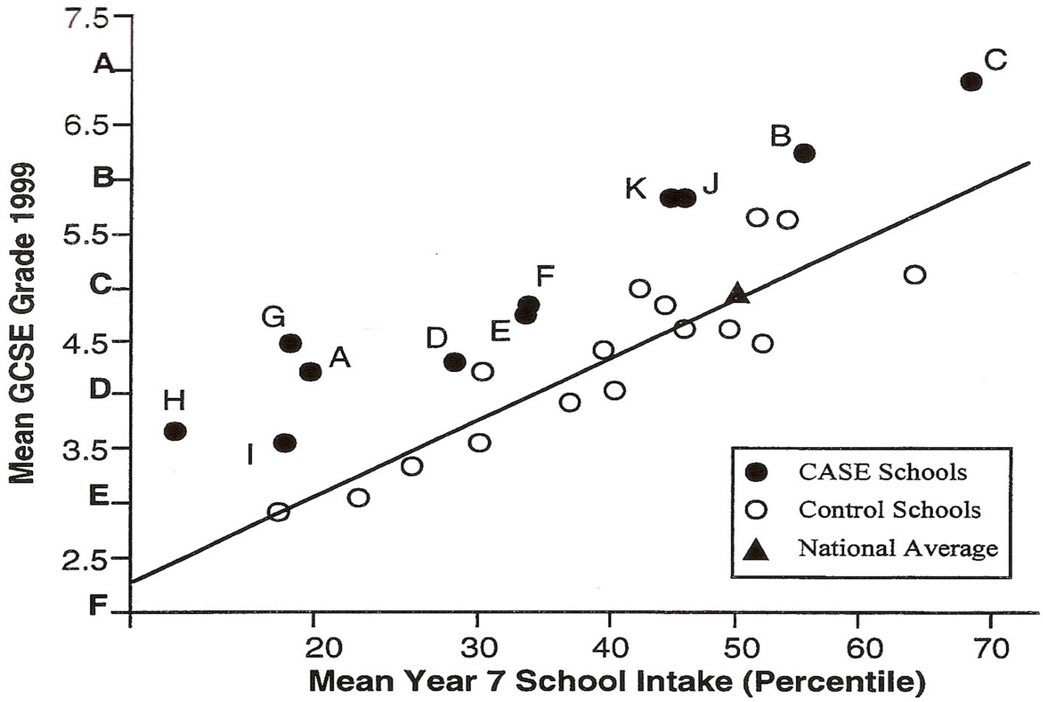

Figure 2.3: 1999 GCSE mean science grade added-value (Shayer, 1999a). Each CASE school is represented by a letter on the graph

For science, the added value averages approximately 1 grade, with all CASE schools making significant gains over control schools. Similar added-value results were observed for mean grades in Mathematics and English, which indicates that the thinking developed within a science context can be transferred to other unrelated areas. The results of this study indicate that the CASE intervention does lead to long-term gains in academic achievement and are reproducible on a large scale. The results did not show a bimodal distribution, which was a feature of the results in the original CASE intervention. This study also showed that the CASE intervention has positive effects on students' academic achievement regardless of their ability prior to starting the programme.

Results consistently show that the CASE intervention has a substantial long-term effect on students' academic achievement, even in subjects not closely related to science (Adey, 1992; Adey & Shayer, 1993; Shayer 1999a; Shayer 1999b). As a result of the success of the original CASE intervention, the cognitive acceleration methodology has evolved both vertically, into all levels of primary school, as well as horizontally, into different subjects. The details of this will be discussed in the next section.

2.6.2 CASE in the Primary School

- CASE at Key Stage 1 (CASE@KS1)

After the success of the CASE II programme at increasing Year 7 and 8 students' general thinking abilities, the researchers began to look at developing CASE programmes aimed at Year 1 students in a disadvantaged area of London. The Key Stage 1 (KS1) experiment differed from the original CASE interventions in a number of ways, namely:

- Aimed at 5 & 6 year olds instead of 11 – 14 year olds
- Based on the schemata of concrete operations
- Initially designed as a 1 year intervention

The intervention was initially designed as a one-year programme on the basis that greater effects could be achieved with much younger children, as one year is 20% of a 5 year olds life and that teachers of young children are generally more focused on pedagogy than on subject matter compared to teachers of secondary school children (Adey *et al.,* 2002). The materials published are known as *Let's Think!* (Adey *et al.,* 2001) and consist as a set of 26 cognitive acceleration lessons plus three introductory 'listening' activities. In practice, the teacher would do the '*Let's Think!'* activity with a different group of 5-6 students every day, while the other students carry on with their other work, so that by the end of the week each student has completed the cognitive acceleration lesson. Each lesson focuses on one of the schemata of concrete operations, as a child at the age of 5 or 6 years is at the entry point to the concrete operational stage. However, the schema of conservation, which is a feature of the concrete operational stage, was purposefully omitted from the lessons as an opportunity to measure transfer effects. Both the pre- and post-tests were developed to determine the effect of the implementation. The tests contained a drawing element and questions related to conservation. These tests were used to analyse whether students could transfer their general thinking abilities developed in the *Let's Think!* activities to areas that they had not covered, with the drawing related to near transfer and the conservation to distant transfer.

The CASE@KS1 experiment began with 14 Year 1 intervention classes in 10 schools, with 8 control classes in 5 nearby schools. Students were administered a pre-test and two post-tests, one immediately after the intervention a second delayed post-test one year later. Over the one-year intervention, the experimental classes made significantly greater cognitive gains than control classes (Adey *et al.,* 2002). Student gains were measured in terms of residual gain scores. The distribution of gain scores made by the intervention cohort over that of the control group, in relation to drawing and conservation at immediate post-test, can be seen in Figures 2.6 and 2.7 respectively. Frequencies of each score are shown as a percentage of the total number in that group. The distribution of gain scores in the drawing test is generally shifted to the right. Intervention students appear to peak at +6 to +8 while control pupils peak at around +2 to +6. For conservation, the distribution reflects that of the original CASE II project with the pattern being bimodal. However, the intervention group make greater gains than the control group overall. There was also no significant gender effect observed in the results at immediate post-test. These results have been reproduced by Cattle and Howie (2008), although on a smaller scale.

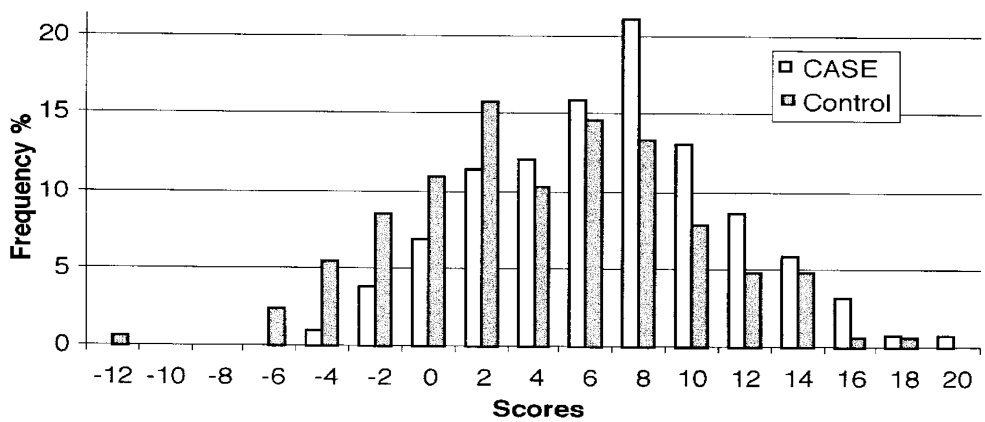

Figure 2.4: Distribution of gain-scores of Year 1 students in Drawing (Adey *et al., 2002*).

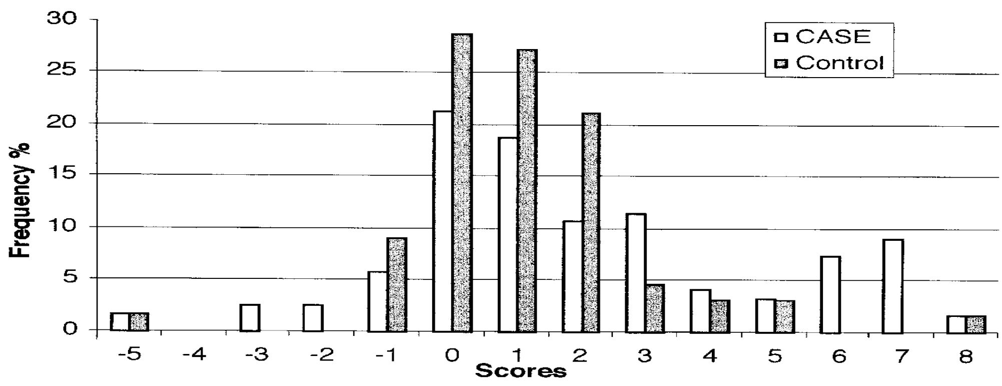

Figure 2.5: Distribution of gain-scores of Year 1 students in Conservation (Adey *et al.,* 2002).

In general, the CASE classes showed greater gains in cognitive development than the control classes, however the bimodality in results highlights that some intervention classes made little or no gains greater than those made by the control group. One year after the end of the CASE intervention, there were no longer any significant differences between experimental and control children in either general intelligence tests or mean achievement scores on national curriculum tests in English and Mathematics, which children sit at the end of Year 2 (Adey *et al.,* 2004). However, there was a trend for classes who had made larger cognitive gains over the period of the intervention to retain longer-term effects in non-verbal intelligence and mathematics assessments. The CASE intervention at KS1 was extended to become a 2-year programme to allow teachers to become familiar with the methodology and to maintain the effects of the intervention (Adey *et al.,* 2004).

- **CASE at other class levels in primary school**

The results of the CASE in Year 1 show that the intervention classes made significant gains in cognitive development over the control classes. However, without continuous cognitive stimulation, a child's developmental process may revert rather quickly back to the norm. To encourage the cognitive stimulation of students in a more consistent manor, the researchers developed a further three CASE intervention programmes for students at primary level:

- *Let's Think!* Early Year (Robertson, 2006);
- *Let's Think through Science!* 7&8 (Adey *et al., 2003*) and;
- *Let's Think through Science!* 8&9 (Adey *et al., 2003*).

The programmes begin with two or three introductory activities to allow the students to become familiar with the structure of the lessons and give the teacher an opportunity to divide the class into suitable groups. The lessons focus on the appropriate schema for each age level. Each schema starts off simply and becomes progressively more challenging throughout the programme. Each of these programmes is discussed in more detail in Chapter 3. Table 2.7 displays all of the materials published for CASE, and the main schemata considered within each set of materials.

Table 2.4: All published CASE materials and the schemata involved

Programme	No. of lessons	Age	Classification	Seriation	Causality	Time Sequence	Spatial Perception	Rules	Concrete Modelling	Combinatorial Thinking	Variables	Conservation	Proportionality	Inverse Proportionality	Probability	Correlation	Equilibrium
Let's Think! Early Years	15	4-5 years	✓	✓	✓												
Let's Think! 5&6	27	5-6 years	✓	✓	✓	✓	✓	✓									
Let's think through science! 7&8	17	7-8 years	✓	✓	✓				✓	✓	✓	✓					
Let's think through science! 8&9	20	8-9 years	✓	✓	✓				✓		✓	✓					
Thinking Science	30	11-14 years	✓						✓		✓		✓	✓	✓	✓	✓

2.6.3 CASE in Ireland

There have been two recent studies in Ireland using the CASE materials, one study at the primary/secondary transition and the other at the early years of primary level. Each of these will be discussed below.

- **CASE across the primary/second level transition**

In Ireland, a cognitive level profile of primary and second level students was obtained which showed that virtually no 6th class primary school pupils (average age 12.3 years and n=621), and little less than 10% of 1st year second level students (average age 12.8 years and n=106) in the study, were at levels capable of formal operational thought (McCormack, 2009). The CASE lessons were implemented across the primary-second level transition with the aim of increasing the percentage of students at this level of thought. The CASE lessons where divided into two programmes and adapted for use in the final year of primary school (*Thinking Science 1*) and the first year at second level (*Thinking Science 2*). Students' cognitive development levels were measured prior to the intervention and immediately afterwards and compared against those of the control classes. Intervention students were classified as either experiencing i) *Thinking Science 1* only, ii) *Thinking Science 2* only or, iii) both *Thinking Science 1 & 2* programmes.

The results showed that for the *Thinking Science 1* group, the intervention cohort made greater gains in cognitive development than the non-intervention cohort with an effect size of 0.51. However, the gains made by each class varied ranging from 0 to 2.3 RGS indicating that some classes made little or no cognitive gains over the control classes, while others made significant gains as can be seen in Figure 2.8. The activities were also delivered through three different arrangements; by the class teacher (previous training provided), by the researcher, and through team-teaching (teacher and researcher). There was no significant difference in the gains made between the three arrangements at this level. This implies that the implementation of CASE lessons with non-specialised science teachers in primary school is possible, and can yield positive effects on pupils' cognitive development.

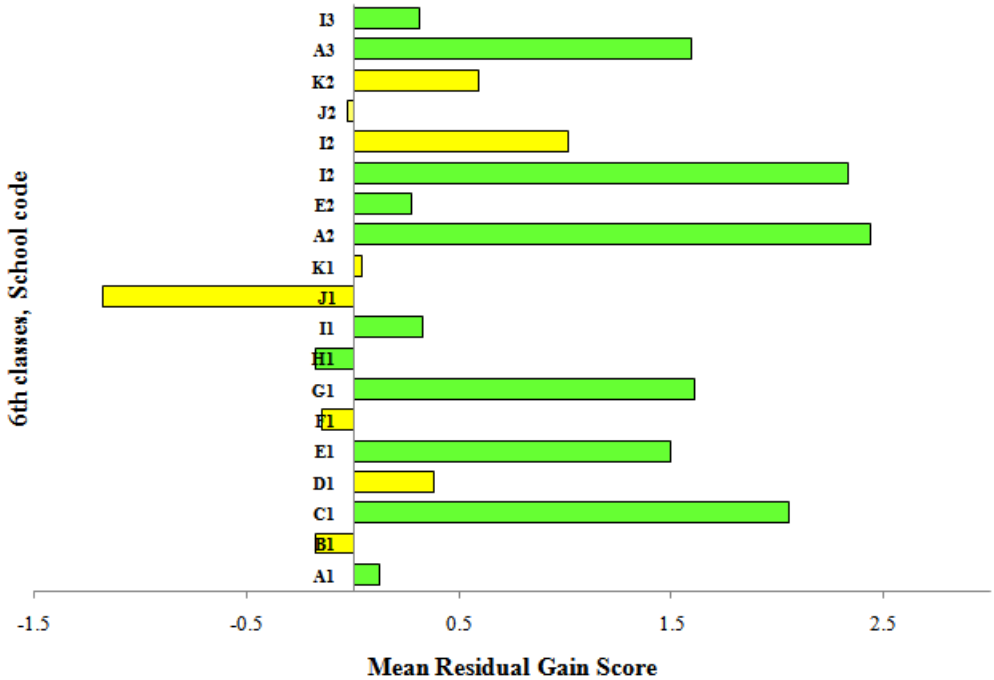

Figure 2.6: Mean RGS for 6th class intervention (green) and non-intervention (yellow) groups (McCormack, 2009). The letters refer to a code used by the researcher and each bar refers to a specific class group that participated in the intervention.

The results for the *Thinking Science 2* group are similar to that of the *Thinking Science 1* with the intervention cohort making greater gains in cognitive development than the non-intervention, with an effect size of 0.52. Again, there was a significant difference in the mean RGS for each class ranging from 0 to 3 as shown in Figure 2.9. The results also showed a degree of bimodality, which was also observed in the results of the original CASE II programme. There was a significant difference in the gains made by students through the three different teaching arrangements at this level, with team teaching yielding the greatest gains.

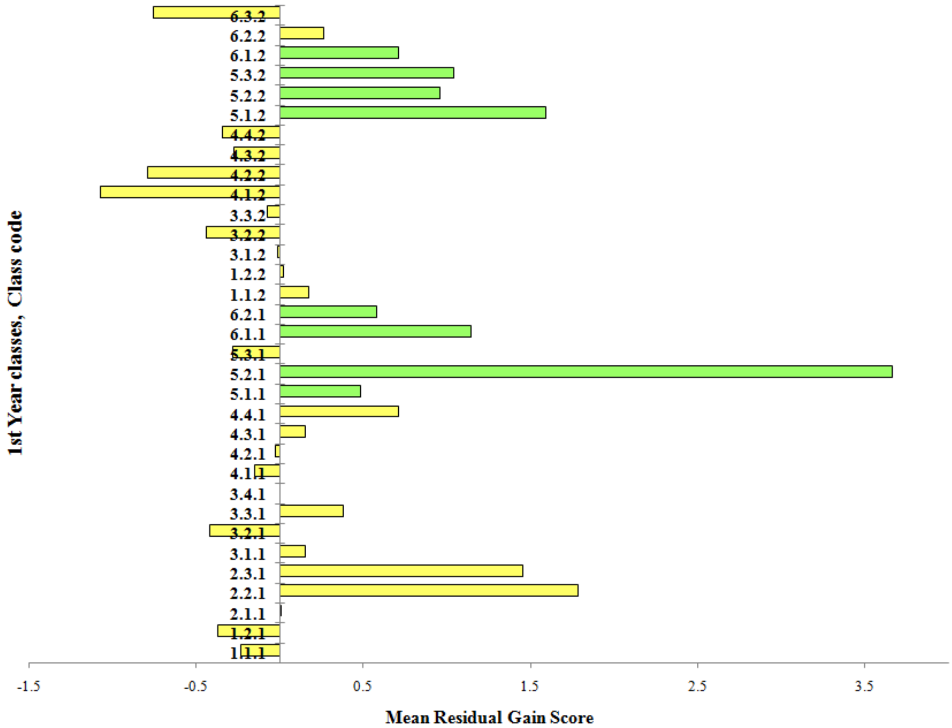

Figure 2.7: Mean RGS for 1st year intervention (green) and non-intervention (yellow) groups (McCormack, 2009). The numbers refer to a code used by the researcher and each bar refers to a specific 1st Year class group that participated in the intervention.

The intervention group who experienced both the *Thinking Science 1* and *Thinking Science 2* programmes made the greatest gains in cognitive development, with an effect size of 1.06, as shown in Table 2.8. The magnitude of this result is similar to those observed in the original CASE II programme.

Table 2.5: Effects of the Thinking Science 1 and 2 programmes on students' cognitive development (McCormack, 2009).

Group	Non – Intervention N	Intervention N	Effect Size
Thinking Science 1	238	304	0.51
Thinking Science 2	449	94	0.52
Thinking Science 1 &2	449	32	1.06

- **CASE in Infant classes in Ireland**

The "*Let's Think: Early Years*" (LTEY) programme (Robertson, 2006) was implemented in two rural primary schools in the northwest of Ireland (Gallagher, 2008). The participants, whose ages ranged from 4.0 – 6.5 years, were in either their first or second year of formal education. The LTEY programme promotes a teaching arrangement that involves dividing the children into groups of four and carrying out the activity with a separate group each day. However, this was considered impractical by the researcher due and the lack of teaching assistants to work with the rest of the children. Therefore, the activities were carried out as whole-class activities. The teacher, as facilitator, moved from group to group prompting, offering scaffolds, inviting students to comment on their progress and to describe the steps taken thus far, to note any areas of difficulty that they encountered and to explain how they overcame these obstacles. Students were administered pre- and post-tests on spatial awareness before and immediately after the intervention. The intervention group made significant gains over the non-intervention group at pre and post-tests, with an RGS of 1.86.

2.6.4 CASE in other countries

The materials of the *Thinking Science!* CASE project have been adapted and implemented in many countries worldwide with similar results being observed.

<u>Australia:</u> Endler and Bond (2001) implemented the CASE *Thinking Science* programme in a co-educational private school with students aged between twelve and eighteen years. One lesson was delivered every 3 weeks for 5 years. Only 29 students remained in the school for the duration of the programme and these students' cognitive levels were tested three times using Bond's Logical Operations Test (BOLT) (1976). The 29 students who took part in the intervention showed significantly greater cognitive development compared to those who had not. Endler and Bond (2001) reported that the greatest change took place between the ages of 13 and 15.

Oliver, Venville and Adey (2012) implemented the CASE programme with students in Years 8 and 9 (12-14 years of age) in a low socioeconomic high school in regional Australia. Their research focused on six science teachers in one school. Students' cognitive level was measured before and after the intervention and compared against control students. The students in the CASE study school made greater cognitive gains over the control students, with an effect size of 0.47. A gender-effect was also observed with male students making greater gains than female, although both male and female students made greater gains than the comparative control students. The sample also included a group of male football specialist students, who made the most significant gains with an effect size of 0.75. Data from national and state-wide examinations was used to determine the gains made by the intervention students compared with the average state gains in relation to science, reading, spelling and numeracy. Students were tested twice in Years 7 and 9 and results reported by the Department of Education for students in Western Australia. Intervention students showed gains greater than the state mean in science and gains close to the state mean in reading, spelling and numeracy. Again the male football specialist students made the most significant gains in relation to science with a mean gain almost twice the state average. This group also made gains greater than the state average in numeracy, however their gains were slightly below average for reading and spelling.

<u>Finland:</u> A unique experiment was carried out in Finland by Hautamäki *et al.* (2002) in which all of the students in Year 6 from one city (20 schools) were individually allocated to one of three conditions: CASE, Cognitive Acceleration through Mathematics Education (CAME) or neither. The students completed the lessons outside of school time. Students in the intervention groups made significantly greater gains than the control groups and far greater than national norms (Adey *et al.,* 2004). However, control students also made gains greater than national norms. The researchers suggest that this is the effect of more constructive dialogue during normal science lessons as a result of two thirds of the students participating in cognitive acceleration interventions (Adey *et al.,* 2004).

United States: Endler and Bond implemented an adapted version of the *Thinking Science!* programme titled *Scientific Thinking Enhancement Project* (STEP) in the US (Endler & Bond, 2008). The teachers in this programme received very little professional development and the number of classes devoted to the CASE intervention was at the teachers' discretion. Typically, one lesson was delivered every 3 weeks with the total number of lessons delivered ranging from 13 – 21. Bond's Logical Operations Test (BLOT) was used to measure cognitive development. Despite the lack of professional development, the results showed a positive correlation between the CASE intervention and student cognitive gains.

Other countries: Studies in Pakistan and Malawi have also shown that the CASE programme is successful at developing student's general thinking abilities. In Pakistan (Iqbal & Shayer, 2000), a study with students aged 11 to 13 years showed that the CASE programme promoted students thinking to the early formal (3A) level while the control group remained at the concrete generalization (2B*) level. In Malawi (Mbano, 2003), a study on 16 and 17 year-old students also showed that the intervention group made significant gains in cognitive level over the non-intervention group. Both studies showed a gender-effect with the male students making larger gains than female students. In Europe, adapted versions of the *Thinking Science!* programmes were also implemented in schools in The Netherlands and in Germany (Adey, 1999a).

2.6.5 Cognitive acceleration in other contexts

- **Cognitive Acceleration through Maths Education (CAME)**

The CAME programme titled '*Thinking Maths*' (Adhami *et al*., 1998) was developed after the *Thinking Science!* programme, by the same group from Kings College in London. CAME follows the same methodology as the CASE programme, however, the focus is on challenging the pupils to 'think' mathematically. 10 schools took part in the intervention and with pre- and post-testing. Pre-post test effect-sizes varied between 0 and 0.55 for each school overall, and from 0.33 to 0.84 standard deviations for each class (Shayer *et al.,* 1999). Three years later, at the end of Key Stage 3, the GCSE results of the intervention group were compared to those of the non-intervention group in Mathematics, Science and English, and against national norms. The intervention group performed better than the control group and national averages in all three subjects, with some slight irregularities in English (Shayer *et al.,* 1999). Two additional CAME programmes have been developed aimed at five and six year old (Shayer *et al.,* 2004) and six to nine year old students (Adhami *et al.,* 2005).

- **Cognitive Acceleration in other Contexts**

Cognitive acceleration programmes have also been developed for use in different contexts including CATE (Cognitive Acceleration through Technology Education) (Hamaker & Backwell, 2003) and *Think Ahead!* (Gouge & Yates, 2006) developing thinking through drama, visual arts and music. Both programmes are designed to promote formal operational thinking skills with adolescents, between the ages of 11 and 14 years. A cognitive acceleration programme *Let's Think through Literacy!* (LTTL) (Gouge & Yates, 2008) has also been developed for children aged 9 – 11 years. All programmes are based on the cognitive acceleration methodology of creating cognitive conflict, generating meaningful classroom discussion and encouraging metacognitive thinking.

Summary

The evidence as detailed above, consistently shows large, long-term, generalised effects of cognitive acceleration on students' intellectual growth. Intervention students make greater gains in cognitive development, and in academic achievement than matched control students. The effects are not limited to science, and similar results have been observed in varied contexts, and at different levels of schooling. However, results from CASE at primary level highlighted that one year after the intervention there were no longer any significant differences between intervention and control students in terms of cognitive development. This suggests that to maintain the effects of the cognitive acceleration intervention, students at this level need to be continuously cognitively stimulated.

2.7 Why does Cognitive Acceleration work?

Adey and Shayer (2011) consider the three pillars of cognitive conflict, social construction and metacognition integral to the efficacy of cognitive acceleration. The cognitive conflict aspect of the lesson provides the stimulation considered necessary for cognitive development. Meaningful dialogue is essential to resolve cognitive conflict and this meaningful dialogue can only be constructed through challenging situations. It is the generation, resolution of, and reflection on cognitive conflict, which drives cognitive development (Adey *et al.,* 2007).

The metacognition aspect of the lesson also plays an important role. Metacognitive knowledge is aimed at understanding the nature of knowledge as well as understanding one's own learning strengths and weaknesses, and its development is an important component of the general process of cognitive development (Adey, 2008). Through planning, regulating and evaluating, students are more in control of their thinking and can solve problems more efficiently (Lai, 2011). Increasing students' metacognitive knowledge has also been linked with better critical thinking (Magno, 2010). Pupils with effective metacognitive skills accurately estimate their knowledge in a variety of domains, monitor their on-going learning, update their knowledge, and develop effective plans for new learning (Everson & Tobias, 1998). Metacognition is also linked to motivation. Researchers suggest that metacognitive thinking includes management of affective and motivational states, and that persistence and motivation improves as the student becomes more aware of their strengths and weaknesses (Martinez, 2006). Adey and Shayer (2011) maintain that it is the integration of all three pillars, which make cognitive acceleration effective. All three aspects of the CASE lessons must be present, and none are sufficient on their own (Adey & Shayer, 2011).

When considering what exactly is developed by cognitive acceleration, Adey (2004) proposes that cognitive acceleration enhances the development of the central processor, as described by Demetriou's model of development (Demetriou *et al., 1993*), by increasing both the working memory capacity and its' efficiency. Working memory capacity increases under the influence of cognitive stimulation; however this development is slow and constrained by the maturation of the central nervous system. The efficiency of existing working memory is improved through the development of more advanced schemata, which progress "as automatic ways of processing information in response to the continued experience of trying to solve problems of different types with constraint provided by maturation" (Adey, 2004).

2.8 Teaching for cognitive stimulation

Cognitive acceleration has consistently shown to generate gains in students' academic achievement and cognitive development in a wide range of subjects and age levels. As a result, Adey and Shayer (2011) consider the question; why isn't everyone using cognitive acceleration? As previously discussed, it is the integration of the three pillars of cognitive conflict, social construction and metacognition that make cognitive acceleration successful. However, more importantly, it is the teacher's management of these pillars that determine how successful the activity will be. Teaching for cognitive stimulation is not easy. There are often no clear objectives, collaborative work amongst students is encouraged, it is not necessary to finish the activity, and students leave the class with no written record of their work. Children need to be "given an opportunity to exercise their own minds, to engage in critical appraisal, to risk opinions in a sympathetic atmosphere and then have the opinions challenged in a rational but respectful manner" (Adey, 1999b). This requires teachers to adopt a pedagogy that is often very different from their current classroom practices (Adey *et al*., 2004).

Venville *et al*. (2003) compiled a list of behaviours that exemplify the types of "good thinking" necessary for cognitive acceleration to be effective. Examples of "*good thinking"* include explaining and demonstrating ideas and actions, making suggestions for solving problems, highlighting discrepancies, adopting new ideas, and working collaboratively (Venville *et al., 2003*). Their results showed that students engaged in "good thinking" more often in a CASE intervention lessons than in control lessons, and that episodes of "good thinking" were provoked by the teacher. The teachers modelled and encouraged evaluative behaviour and asked for alternative solutions and explanations. To foster good thinking in the classroom, Venville *et al.* (2003) recommend that teachers accept challenge as a central part of the lesson, encourage students to explain their ideas, and create an environment where "thinking is a valued classroom process". Teaching cognitive acceleration lessons is the opposite of teaching for recall or factual knowledge, and requires students to be given the opportunity to think for themselves (Adey, 1999b).

In addition to being able to generate and manage challenge that is productive for each child, teachers should encourage their students to become conscious of their own thinking. Thinking needs to be made explicit in the classroom so that metacognitive perspectives can be adopted, and transfer of learning improved (McGuinness, 2005). Adey (2006) considers eliciting metacognitive thought as one of the more difficult aspects for cognitive acceleration teachers. This type of teaching is often far removed from teachers' current practices and requires an extensive professional development programme.

2.9 Preparing teachers to teach CASE

Professional development (PD) is widely believed to be necessary to support implementation of new teaching strategies, especially those that require changes in teacher's classroom practices (Garet *et al.* 2001; Smylie, 1996). Teaching for cognitive stimulation requires teachers to understand the underlying theory, generate and manage cognitive conflict situations, facilitate meaningful dialogue between students and encourage students to reflect on their own thinking. The main aim of the CASE III research project, undertaken by Michael Shayer from 1989 to 1991, was to gain a deeper insight into the classroom process that maximize cognitive development in 11-14 year olds. Professional development for CASE is based on the research of Joyce and Showers (1980) which highlighted features of effective professional development, including:

- The presentation of information on theory;
- Demonstration of new skills by the trainers;
- An opportunity for participants to practice their new methods;
- The provision of feedback to participants;
- Coaching of participants in their own classroom to assist with the transfer of new skills and strategies.

(Joyce & Showers, 1980)

They noted that successful professional development programmes can increase teachers' knowledge about, and skill in using, new methodologies and generate a change in their classroom practices.

The CASE PD programme

Professional development for CASE consists of a combination of INSET (in-service education for teachers) days and coaching visits to observe the teachers in action. The PD programme typically lasts for two years paralleling the two-year CASE programme. The programme is front-loaded, with the majority of the INSET days near the beginning, but with contact continuing throughout the PD. This allows the teacher's time to prepare, not only technically but also mentally, before the start of the school year (Adey *et al.,* 2004). The INSET days reflect the pedagogy of CASE itself. Teachers are provided with some challenge, encouraged to talk and to listen to each other, and to reflect on how their own perspectives have changed (Adey, 2006). The basic structure of processional development for CASE is outlined in Figure 2.10.

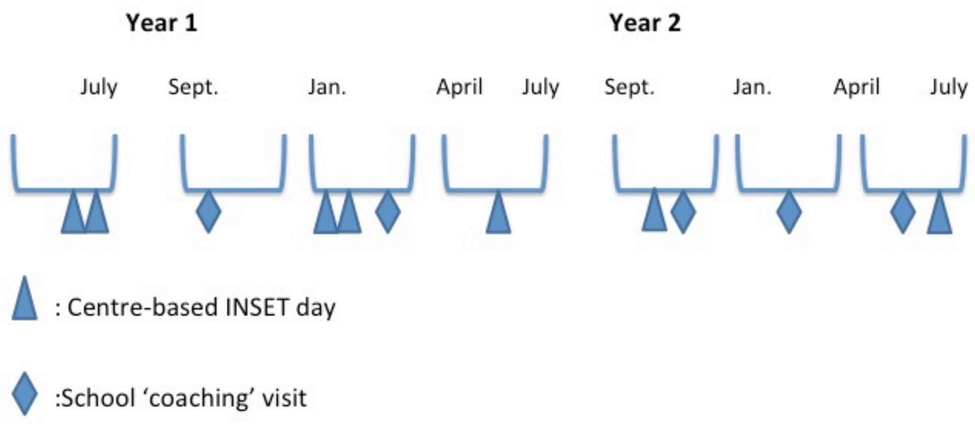

Figure 2.8: Pattern of activities in a typical CA PD programme (Taken from Adey *et al.,* 2004)

This framework contains features that are widely recognised as elements of successful professional development.

- **Focus on theory**

It is widely believed that successful professional development programmes need a theoretical foundation and a conceptual framework (Fullan, 1993). In order to teach the CASE lessons effectively, teachers need to be given sufficient time to study the underlying theory of the cognitive acceleration methodology. Teachers should be afforded an opportunity to become familiar with their new strategy, to argue about alternative approaches, and to build new skills rooted in understanding (Adey *et al.,* 2004). Successful implementation of a cognitive acceleration lesson does not require simple technical skills, rather, the teacher needs to be competent at setting up cognitive conflict situations, encouraging constructive argumentation and eliciting metacognitive thinking in their students, skills which will only develop through understanding the underlying theory (Adey, 2006).

- **Duration**

The CASE professional development programme was designed to last for two years, paralleling the two-year CASE programme. Teachers require a considerable amount of time to change their classroom practices with Joyce & Weil (1986) claiming that it takes at least 30 hours of practice to perfect a new teaching technique. Professional development, which lasts for longer periods of time, allows for multiple cycles of presentation and integration of, and reflection on knowledge (Blumenfeld *et al.,* 1991). The results of research carried out by Birman *et al.* (2000) showed that professional development of longer duration tend to focus on subject-area content, have opportunities for active learning, and more coherence with teachers' other experiences than do shorter activities. However, simply providing more time for professional development does not guarantee that this time will be used wisely. Kennedy (1998) showed that differences in duration of professional development activities were unrelated to improvements in student outcomes. Therefore, although professional development clearly requires time, this time must be well organised, carefully structured, and purposefully directed (Guskey, 1999). Guskey and Yoon (2009) analysed a number of studies ranging from five to over 100 contact hours and those which resulted in positive student outcomes, included 30 or more contact hours while other research suggested that activities should be spread over a term and include at least 20 hours (Desimone, 2009).

- **Practice**

Teachers are given the opportunity to practice implementing the lessons during INSET days and during coaching visits to the school. During INSET days, teachers can become familiar with new CASE activities and discuss possible strategies to implement the lessons successfully. During coaching visits, teachers are observed or participate in team teaching with the CASE tutor. The teacher retains overall control of the class while the CASE tutor can interject during the lesson with permission from the teacher. Monitoring and coaching of teachers are widely believed to be features of effective professional development. These types of activities usually provide teachers with an opportunity for in-depth engagement with their new methodology (Putman & Borko, 2000). Discussion after the lesson where the teachers are offered feedback and can reflect on, and evaluate their implementation is essential (Adey *et al., 2004*). Coaching visits may also involve the teacher observing a demonstration lesson, however, to be effective, Adey (2004) believes that the demonstration lessons should only be done if i) observing teachers have already made an attempt at teaching CASE lessons themselves, so that they can recognize the key features of a CASE lesson and apply it to their own teaching, ii) observing teachers are given specific things to look for in the lesson such as questioning, involving the whole class or eliciting metacognition and, iii) where a teacher states that it will not work in their classroom. The ultimate purpose of the coaching visits is to assist teachers in changing their practice through observation, feedback and demonstrations. The teachers should be given sufficient time to reflect upon what they have heard/seen and how it applies to their own teaching. Ideally, each teacher would have three coaching sessions over the course of the PD programme however, this is not always possible for cost reasons, and some may only receive as few as one session (Adey *et al.,* 2004).

- **Belonging**

For change to take place in a school it is essential for the teachers involved to be able to work together to discuss the new method with one another as the change is gradually implemented. Teachers often report that participating as a group in professional development can provide the motivation needed to work through any problems they may encounter together and builds a sense of community within the school (Little, 1993). Adey (2004) attributes the failure of teachers to continue with the CASE II programme after the intervention to the lack of opportunity to communicate with other teachers. All subsequent CASE interventions/PD have focused on whole science departments and groups of teachers. Teachers should be able to talk informally about any issues or difficulties so that these issues become learning opportunities instead of failures. Discussions between teachers who confront similar issues can facilitate change by encouraging the sharing of solutions to problems, as well as creating the sense that, improvement is possible (Garet *et al*., 2001). Ball & Cohen (1996) report that teachers can also learn from colleagues who are more expert than themselves, creating a community of practice within the school. In departments where cognitive acceleration has been implemented successfully, there is an ethos of sharing experiences through meetings, mutual observations and team teaching (Adey *et al.,* 2004).

This chapter has provided an overview of the CASE methodology, including its theoretical background and classroom methods. Its' positive effects on developing students' thinking skills suggests that it is a possible approach to develop Irish primary students HOTS. The implementation of the CASE methodology at all levels in an Irish primary school, and its evaluation are discussed in the following chapters.

Chapter 3

Methodology and Pilot Study

Introduction

This chapter is divided into five sections. The first two sections (3.1 and 3.2) provide a general overview of the study, including a description of the research methodology and data sources employed. The third section (3.3) presents the results of a small-scale pilot study, and discusses its implications for the main phase of data collection. The fourth section (3.4) maps the existing CASE programmes onto the Irish primary science curriculum, and highlights a number of adaptions necessary to make the lessons suitable for use in the Irish educational system. Finally, Section 3.5 outlines the programme design for the whole-school implementation phase of the study.

3.1 Overview of the study

The positive outcomes of the CASE methodology have been discussed in Chapter 2. This study proposes that the CASE methodology is a suitable approach to address the concerns regarding the under development of Irish students' HOTS within the teaching of primary science. The aims of this research project are to:

a) Assess whether the existing CASE programmes can be integrated into the teaching of science in Irish primary schools and,
b) To evaluate the teachers' implementation of the lessons and identify areas of difficulty

The research method employed in this study was a case study within the empirical - phenomenological research domain employing qualitative research methods. The case study approach attempts to capture the complexities and allows for an in-depth understanding of a particular 'case' in a human and 'real' setting (Stake, 1995 p.xi), which in this study is a school. Case studies are favourable when a 'how/why' question is being asked about "a contemporary set of events over which the researcher has little or no control" (Yin, 2014 p.14) but which form 'elements' of the phemonenon being investigated. Limitations of case study research include difficulty in generalizing the findings from a single case study, and a lesser degree of experimental rigor (Yin, 2014). A vital step in carrying out case study research involves defining the case and context being analysed. In this study, the case was the school, including the following elements: i) the school environment, ii) the children, and iii) the principal and teachers. The context was the introduction of the CASE methodology implemented in a school-wise fashion.

The case study approach employed also involved multiple embedded 'units of analysis' (Yin, 2014). Embedded case studies allow the researcher to analyse the context as a whole while also examining specific units. In this research, the embedded units of analysis are particular class levels which are further divided into sub-units of analysis at the individual teacher level. These subunits of analysis add opportunities for "extensive analysis enhancing the insights into the single case" (Yin, 2014 pg.56). An overview of the case study design used in this research is presented in Figure 3.1. A pilot case study was also employed as a preliminary step in this research. The aim of this pilot study was to develop and refine the planned research questions and procedures that were later used in the formal case study (Yin, 2014).

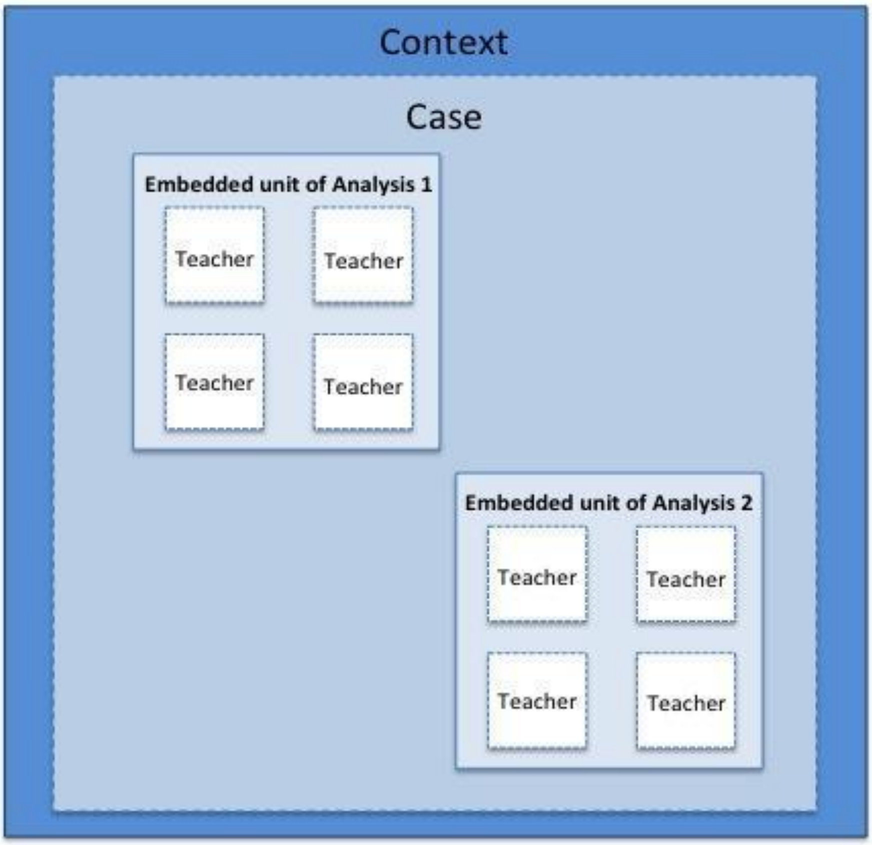

Figure 3.1: Overview of the case study design used in this research

This study is primarily qualitative but uses quantitative methods. In recent years, the mixed methods approach has been favoured by researchers, as they believe that using mixed methods can overcome the disadvantages that a single method has by itself (Creswell, 2003; Tashakkori & Teddlie, 1998). Mixed method research often includes a core component, used to answer the research question, and a supplementary component used to inform the other method and create a deeper understanding of the problem (Morse & Niehaus, 2009). In this study, the core component is qualitative data, which is informed by quantitative data. By including both quantitative approaches and qualitative data in a case study, both the process and the outcome of a phenomenon can be analysed and explained (Tellis, 1997).

Data was collected throughout this research from several different sources. Numerical data was analysed using Multi-dimensional Scaling (MDS) analysis using the ASCAL protocol in SPSS v21.0.

This research study involved four main phases, as shown in Figure 3.2. Firstly, the objectives of the CASE methodology were mapped onto the objectives of the Irish primary science curriculum for each class level, and the degree of overlap between the two analysed. The next phase involved a small-scale pilot study, in which four teachers implemented the existing CASE materials and trialled data collection methods. The CASE materials were then adapted and data collection methods refined for use the final phase of the study, which involved the whole-school implementation of the CASE methodology. The participating teachers' implementation of the CASE materials was analysed using quantitative methods and areas that teachers need support in were identified.

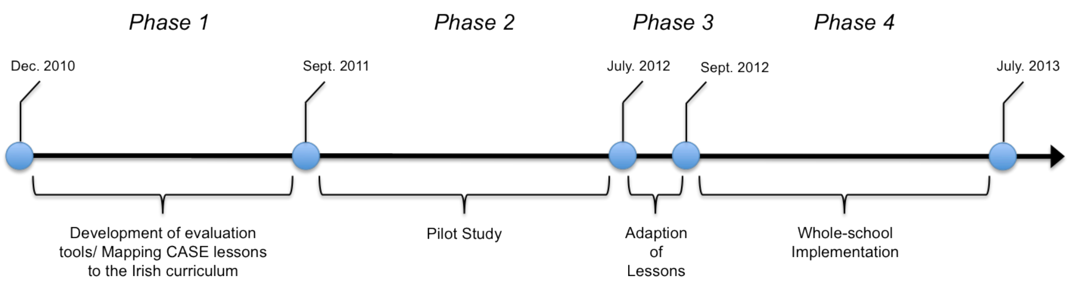

Figure 3.2: Timeframe of research project

Ethical considerations and notation used

In this research, the different sets of data were gathered at different periods of time. In order to track individual change, and to ensure that the teachers' information remained confidential, a coding system was applied. Teachers were numbered one to thirty-one. When discussing a teacher in the text they are referred to using the shorthand "T" followed by their assigned code number e.g. teacher 20 is referred to as T20. Each lesson in the programme was also numbered and signified by the letter L. The questionnaires administered at the beginning and end of the programme are referred to as questionnaire 1 and questionnaire 2 respectively (Q1 and Q2 for short).

When quoting a teacher, the notation indicates the specific teacher and the source of the quotation e.g. (T20.L7) denotes a quote from teacher 20 in lesson 7. As the number of teachers involved in the study is small, the participants were cautioned that anonymity could not be guaranteed but were assured that all information gathered would be treated confidentially and not credited to a named individual. All data was coded and stored in a research laboratory in Dublin City University. Only the researcher and supervisors have access to the data which will be stored for a period of five years.

Table 3.1 Notation used throughout text

Notation	
Teacher	T
Lesson	L
Questionnaire	Q
Observation	O
Field note	FN
Focus group	FG
Interview	IV

3.2 Data collection methods

A variety of data sources were used in this research to completely understand the multifaceted situation. Data sources comprise of both qualitative and quantitative elements.

- **Interviews**

Individual interviews were conducted as part of the pilot study. Teachers were interviewed at the end of the first term (IV1) and again at the end of the academic year (IV2). The interview schedules for interview 1 and 2 can be found in appendix A and appendix B respectively. An advantage of conducting interviews is that they are more flexible than questionnaires and the interviewer can probe the interviewee for clarity or for more detailed information when needed (Gillham, 2005). Interviews can, however, be subjected to researcher bias if the interviewer searches for answers that confirm his/her perceived notions (Borg, 1981). Borg also highlights that the responses given by the interviewee may be influenced by a desire to please the interviewer. In this study, caution was taken by the researcher to eliminate any possibility of bias by facilitating the discussion without influencing the teachers' responses. Interviews conducted as part of the pilot study were purely qualitative. The main purpose of these interviews was the evaluation of the pilot programme and to elicit the teachers' perspectives on the CASE methodology. The interviews were semi-structured in nature, consisting of a combination of open and closed questions. One of the strengths of a semi-structured interview is that it "facilitates a strong element of discovery, while its structured focus allows an analysis in terms of commonalities" (Gillham, 2005 p.70). Each interview, which lasted approximately one hour, was recorded and later transcribed. Questions focused on the teachers' perception of the CASE methodology, supports they felt necessary to implement the lessons effectively and any influences the intervention had on their students, and on their teaching of science. The findings from these interviews informed the programme design for the whole school implementation phase of the study. The interview schedule from Interview 2 was also a preliminary stage in the development of Questionnaire 2, which was administered to all teachers at the end of the whole school implementation. After evaluating the interview transcripts, questions were developed and rephrased accordingly to avoid misinterpretation.

- **Questionnaires**

Questionnaires were used in this study to gather general information about the teachers and their practices and perspectives concerning the teaching of science. Teachers were administered questionnaires before and after the research project. The use of questionnaires as a method of data collection has a number of advantages. Questionnaires encourage pre-coded answers, provide standardized answers, allow the respondent time to think before answering, can eliminate any researcher bias and can be given to a large group simultaneously (Denscombe, 2003). Disadvantages include low response rate, nonresponses to selected items and vague answers to open-ended questions.

During this research project, teachers completed two questionnaires, both of which comprised of quantitative and qualitative elements. The first questionnaire (Q1) was trialled with the selected teachers at the beginning of the pilot programme and administered again to all teachers prior to the whole school implementation of the CASE methodology. This questionnaire sought to elicit answers about teachers' scientific background, and their practices and perspectives concerning the teaching of science before the implementation of the CASE methodology. The 40-item questionnaire (Appendix C) consisted of closed, open and Likert scale questions in 5 sections and was adapted from a questionnaire used in a previous research project (Coulter, 2012). The questionnaire was distributed to all teachers within the school (N=31). This questionnaire provided a general profile of the teachers, which includes details on how they teach science, their confidence levels with a variety of aspects of science teaching and how important they feel the scientific skills are. Teachers were administered a second questionnaire (Q2) at the end of the academic year. The 37-item questionnaire (Appendix D), which was derived from the interview schedule given to teachers at the end of the pilot study, also consisted of closed, open and Likert scale questions in 4 sections. The purpose of this questionnaire was to establish whether or not there had been any change in individual teachers' attitude towards teaching science, their views on the CASE methodology and any effects they felt it had on their students.

The teachers were administered a third questionnaire (Q3) following the whole-school implementation of the CASE methodology (Appendix E). This questionnaire focused on the teachers' understanding of the concept of metacognition and is discussed in more detail in Chapter 7.

- **Lesson Reflections**

At the end of each lesson teachers were asked to complete a written lesson reflection (Appendix F). The 17-item reflection contained closed, open and Likert-scale questions. The questions were developed to gather information on the teachers' confidence regarding different aspects of the lesson, how they guided their students through each pillar during the lesson and areas of achievement/improvement. Lesson reflection templates were initially trialled in the pilot study. Questions were modified to generate the final version that was used in the main study. A description the lesson reflections analysis is given in Chapter 4.

- **Observations**

Observations were used as a data collection method in both the pilot and main phase of this study. Observations allow the researcher to directly see the actions of the participants without having to rely on what they say they do and can allow for a relatively objective measurement of behaviour (Tashakkori & Teddlie, 1998). In this research, observations played a significant role in understanding the multifaceted situation. Observations in the pilot study were purely qualitative and used to gain an in-depth understanding of the teachers' classroom practices. Observations during the whole school implementation involved intra-method mixing, capitalizing on the strengths of both quantitative and qualitative observations. A semi-structured instrument was used including open, closed and Likert scale questions (Appendix G). The researcher took the role of participant-as-observer, becoming involved in the lesson by team-teaching or helping students carry out experiments, while also taking extensive field notes.

- **Focus Groups**

During the whole school implementation of the CASE methodology, regular focus group interviews were held with teachers. Focus group interviews are useful in that some people are more confident in voicing their opinions when part of a group (Glesne & Peshkin, 1992). These interviews, which were held every six weeks, were purely qualitative and semi-structured in nature. The researcher guided the discussion with pre-prepared questions but allowed the conversation to flow naturally when necessary. This type of guided group discussions can generate a rich understanding of participants' experiences and beliefs (Morgan, 1998).

- **Field notes**

Field notes were taken throughout the research project to further inform the study. Field notes were taken during lesson observations and also during informal discussions with teachers about the CASE methodology. These notes were then used to inform the discussion during the focus groups, and offer more in-depth feedback to the teachers.

Table 3.2 describes the main phases of this research study and the purpose, number of participants and data collection methods used.

Table 3.2: Timeline of the research study and data collection methods used

	Timeline	Study	Purpose	Participants	Data Collection	Quantitative/ Qualitative
1	December 2010- September 2011	Development of evaluation tools	Development of suitable data collection methods			
2	September 2011 – June 2012	Pilot Study	To assess the suitability of the CASE programmes for the Irish curriculum. Trial and modify data collection methods	Teachers (N=4)	Questionnaire Lesson Reflections Interview Observations	Mixed Qualitative Qualitative Qualitative
3	June 2012 – September 2012		Evaluation of pilot programme and adaption of CASE lessons to fit with the Irish Curriculum			
4	September 2012 – June 2013	Whole-School Implementation	Implementation of the CASE methodology at all class levels	Teachers (N=31)	Questionnaire Lesson Reflections Observations Focus Group Field notes	Mixed Mixed Mixed Qualitative Qualitative

3.3 Pilot Study

The pilot study, which began in September 2011, was purely qualitative involving 4 case studies on individual teachers. This small-scale study was used as a preparatory stage for the whole-school implementation of the CASE methodology. Its' role was to evaluate the suitability of the CASE programmes in the Irish curriculum and to refine data collection methods, such as questionnaires and lesson reflections, for use in the main study. Empirical observations from the pilot study were used to inform the whole-school implementation phase of this research. A timeline of the pilot study is shown in Figure 3.3.

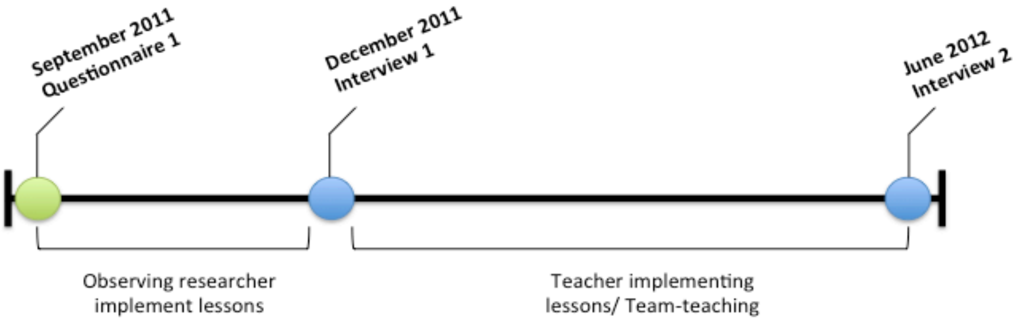

Figure 3.3: Timeline of pilot study

Participants

Four teachers voluntarily participated in the pilot study. All four teachers cited a desire to develop their science pedagogical knowledge as the reason for participating in the programme. The teachers who took part in the study were from different class levels which as shown in Table 3.3.

Table 3.3: Class level of teachers participating in pilot study

Teacher	Class Level
T2	Junior Infants
T12	1st Class
T24	4th Class
T29	6th Class

The teachers' responses to Q1 indicate that the teaching experience varied among the participants, ranging from 9 to 34 years. Two of the four teachers had over 25 years primary teaching experience. In relation to previous science experience, T2, T12 and T24 completed science modules at university and felt that these sufficiently prepared them to teach primary science. T29 did not complete any science modules at university. T2 and T24 participated in the in-service provided by the PCSP following the introduction of the revised curriculum in 2003. The pilot teachers considered themselves confident or very confident in their scientific content knowledge, however in contradiction to this, all four teachers cited a lack of content knowledge as their main weakness in teaching science. T2, T12 and T24 mention a personal interest in science as their main strength as a science teacher. T29 considered her main strength as a science teacher, was that she allows her students to investigate independently. All four teachers considered the development of the students' scientific skills as very important, and placed a heavy emphasis on the development of skills such as questioning, predicting, observing, and analysing. All teachers consider class size, a lack of equipment and a lack of adequate training as the main factors that inhibit them in teaching science.

Programme design

An initial focus group was held at the beginning of the year involving all four participants. Teachers were introduced to the CASE methodology and the lessons to be taught that year. On average, one lesson was delivered every two weeks. Teachers initially observed the CASE lessons being implemented by the researcher until December 2011 (4 lessons). Teachers were interviewed individually at the end of the first term to gain an insight into their attitudes towards the CASE methodology. At the beginning of the second term, teachers began to implement the lessons themselves. The delivery of the lessons varied, with some lessons taught solely by the class teacher and others taught through team teaching. Each teacher taught between 5 and 8 lessons during the pilot study. Table 3.4 presents the lessons taught by each teacher, which can be linked to the CASE programmes described in more detail in Section 3.4.2. An overview of the delivery of the lessons is shown in Table 3.5. Teachers were interviewed individually again at the end of the year.

Table 3.4: CASE lessons taught by each teacher participating in the pilot study

	T2	T12	T24	T29
1	Colourful flowers	Clown Faces	Climb that Mountain	Climb that Mountain
2	Where do I live?	Sticks	Make that Box	Make that Box
3	What do I Eat?	Marble Run	Who am I?	What Varies?
4	My Senses	Sorting Shapes	All these Bones	Two Variables
5	Castles at the Seaside	Farm Animals 1	What makes me move?	What Sort of Relationship? 1
6	At the Seaside	Farm Animals 2	Where do I live?	What Sort of Relationship 2
7	Mixed-up Stories	Boxes	How am I adapted?	The 'Fair' Test
8	Where are my Toys?	Cooking	What am I?	Rollerball
9	How Do my Toys Move?	Guess What?	Where does it Belong?	Gears and Ratio
10	Holes		I cant find the sugar	Bean Growth 1
11	Who are we?			Spinning Coins
12				Floating and Sinking

Table 3.5: Method of delivery of each lesson during the pilot programme

Teacher	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
T2	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	
T12	✓	✓	✓	✓	✗	✗	✗	✗	✗			
T24	✓	✓	✓	✓	✗	O	O	O	✗	✗		
T29	✓	✓	✓	✓	✗	O	O	O	O	O	O	O

✓ Researcher led
✗ Class teacher led
O Team-teaching

3.3.1 Evaluation of the Pilot Study

The pilot teachers' implementation of the CASE lessons and attitudes towards the CASE methodology were analysed and used to inform the whole-school implementation phase of the study. This analysis considers the teachers' responses to IV1, IV2 and researcher observations.

a) Teachers' attitudes towards the CASE methodology

The general attitude towards the cognitive acceleration methodology was a positive one. Teachers appreciated the opportunity to encourage their students to think for themselves. The teachers also liked the idea of moving away from one right answer and focusing on the thought process involved. They considered the cognitive acceleration approach to be '*what good teaching looks like"* (T12.IV2) but felt that it was not always possible to teach like this with curriculum demands and other pressures. In general, the teachers found the CASE lessons easy to implement as they were *"laid out step-by-step*". (T24.IV2)

Teachers' engagement with the methodology varied. Despite enjoying the lessons, T2 and T29 did not consider there to be a significant difference in the CASE methodology and a typical science lesson that they have previously taught. "*I try to always teach my science lessons like that so it was not something new to me*." (T29.IV2) However, this did not correlate with the researchers observations as this particular teacher often missed the point of the lesson, and tended to prematurely reveal the outcome of the lesson to her students.

T12's perception of the CASE methodology was more encouraging. The lessons made her very conscious of language and she was surprised to see the difficulty her students had in articulating their thought processes. She noticed that some children, who she considered very intelligent, were "*barely able to put a sentence together*" (T12.IV2). When given a task, her students automatically began to manipulate the equipment but could not verbalise their thinking when stopped and asked to explain what they were doing. T12 believes that textbooks have removed the need for students to think and to speak for themselves. She feels that the cognitive acceleration lessons focus on specific language, which she called "*the language of problem solving*".

> "*Old fashioned teaching where you let the students speak is gone. The language in these lessons is not talking for talking's sake, it is the language of problem solving*" (T12.IV2)

All four teachers commented on how much their students enjoyed the lessons and how engaged they were. Students enjoyed the hands-on aspect of the activities, working in groups and the opportunity to give their own opinions. Teachers found that most of their students enjoyed being challenged, which encouraged the teachers to try to incorporate an element of challenge into other areas of their teaching.

The teachers felt that their questioning skills and ability to manage whole-class discussions improved as the programme progressed. "*I'm better able to facilitate the students thinking, rather than just jumping in and telling them the answer*" (T12.IV2).

The teachers did face some problems in attempting to teach the lessons. All four teachers devoted a lot of time to the 'concrete preparation' stage of the lesson, which often led to the metacognition phase being omitted due to time restrictions. The teachers also found it difficult to mange whole-class discussions at times.
T12 highlighted that not telling the students the answer was the most difficult aspect of the lessons while the other participating teachers said they did not find any aspect of the lessons difficult.

b) The CASE programme

All four teachers found the terminology used in the CASE lessons confusing. When questioned, teachers could describe the main pillars of the lesson but often found

the names difficult to remember. Teachers stated that this lead to some difficulty when completing the lesson reflection sheets.
T24 and T29, were consistently confident in their scientific content knowledge, however, researcher observations indicate that the teachers often lacked sufficient content knowledge to implement the lessons successfully. T24 and T29's perception of how successful the lesson was often did not agree with the researchers observation. This suggests that T24 and T29 were over confident in their ability to implement the lessons successfully.

T2, T12 and T24 found the lesson plans easy to follow and cited them as an important resource as they tried to implement the new methodology. Lessons in the *Let's Think!* and *Let's Think Through Science!* programmes (4 - 9 years of age) are written in great detail under the headings of the main pillars. Suggested questions and dialogue between teacher and pupil is printed in bold in the lesson plan for the teachers to follow. However, T29 was often overwhelmed by the lesson plans for the 6^{th} class group. The lessons implemented in this phase of the research were initially designed for use in secondary schools with subject specific science teachers. Strategies to help teachers guide their students through the main pillars are discussed within these lessons, however, there are no recommended questions to ask, or script to follow. T29 found this rather difficult, especially at the beginning of the programme when her questioning skills were not quite as developed. T29 also found that some of the lessons were too long for students at that age level. Important areas of the lesson, for example, the metacognition stage, were being rushed or omitted completely.

c) Research Design

One clear outcome from the pilot study was that observing the CASE lessons being implemented by the researcher was of little benefit to the teachers. The teachers did not know enough about the methodology to focus on any of the main aspects of a cognitive acceleration lesson, or to highlight any differences between the teaching approach used in a CASE lesson and a 'normal' science lesson. Teachers did not engage with the lessons and paid very little attention to the strategies used to guide students through the main pillars.

> "*I didn't get it in the beginning because I wasn't participating, so I didn't know where it was going. I didn't understand it really. And I didn't learn anything because I wasn't teaching it.*" (T12.IV2)

Team teaching proved beneficial for most teachers. Once teachers had attempted to teach the lessons themselves, they were able to highlight areas that they struggled with, or found difficult. Team teaching allowed the teachers to observe alternative strategies to overcome any problems that they were having, such as response to questions and eliciting metacognitive thinking in their students.

The teachers often lacked the background information on the cognitive acceleration methodology required to implement the lessons effectively. At the beginning of the programme, teachers were introduced to the cognitive acceleration methodology and some sample lessons, however, this was never re-visited. T12 and T24 commented that they would like to know more of the underlying theory of cognitive acceleration, and felt that it may help with their implementation.

The teachers also felt overwhelmed at the volume of lessons that they were given at the start of the year and felt that they did not know enough about the lessons to implement them successfully.

3.3.2 Implications for the main study

In general, the teachers' attitudes towards the CASE methodology were positive. Students enjoyed the lessons and the teachers' questioning skills and ability to facilitate classroom discussions improved. Some teachers did not see a significant difference between the CASE lessons and science lessons that they usually teach. However, these teachers often missed the point of the lesson and revealed the endpoint of the lesson to their students. The teachers did encounter some difficulties in implementing the lessons, including spending too long on the pillar of concrete preparation, accidently revealing the endpoint of the lesson and overlooking the metacognition phase of the lesson.

The evaluation of the pilot study led to a number of implications for the whole-school implementation phase of the project. The underlying theory of the CASE methodology and effective management of the pillars were discussed in more detail with the teachers prior to implementing the lessons. This was regularly revisited during the year, in focus group meetings and during individual discussions with teachers. Teachers were also introduced to the lessons to be taught in sets of three, every six weeks. In this way, teachers were given the opportunity to become more familiar with the science content involved and the most effective strategies for guiding the students through the pillars of the lesson.

The layout of the teacher guidelines for the *Thinking Science!* activities was also altered to follow the same format as the lessons aimed at younger students where suggested dialogue between teacher and student is integrated as part of the lesson plan. A number of lessons were also shortened and language simplified to be suitable for use with children in primary school. This is discussed in more detail in Section 3.4. To resolve the misunderstanding surrounding the terminology, the pillars of the CASE lessons were appropriately rephrased, as shown in Table 3.6

Table 3.6: Renaming of the pillars of the cognitive acceleration methodology

Pilot Programme	Whole-school Implementation
Concrete preparation	Introduction
Cognitive conflict	Challenging Event
Social construction	Discussion
Metacognition	Thinking about Thinking
Bridging	Bridging

Observing the researcher implement lessons proved to be of little benefit to teachers participating in the pilot study, therefore, teachers in the main study began teaching the CASE lessons themselves from the beginning of the year. Opportunities for team teaching were only offered to teachers after they had attempted to teach the lessons themselves and could highlight areas that they felt needed development.

The main points of evaluation from the pilot study are summarized in Table 3.7. These outcomes were used to inform the lesson selection and professional development framework for the whole school implementation phase of the study, which are discussed in Sections 3.4 and 3.5.

Table 3.7: Main points of evaluation of the pilot programme and their implication for the next phase

Evaluation	**Implication for whole-school implementation**
Difficulty in remembering names of pillars	Pillars were appropriately renamed
Lack of scientific content knowledge	More regular and in-depth discussion on the science content and the schema involved in the lessons
Unsuitability of layout of lessons at the 5th and 6th class level	Lessons were adapted to follow the same format as the CASE lessons aimed at the lower levels of primary school
Lack of understanding of the CASE methodology through observation	Teachers began by teaching the CASE lessons themselves, followed by opportunities of team teaching
Lack of background knowledge on the CASE methodology	More in-depth analysis of methodology prior to ad during the programme
Sense of being overwhelmed and unfamiliar with CASE lessons to be taught	Teachers were be introduced to lessons in sets of three, every six weeks and lessons discussed in more depth

3.4 CASE throughout the Irish primary school

The existing CASE programmes were originally designed for use in the English & Welsh school system. A comparison of the education systems of England & Wales and Ireland was carried out to analyse whether the existing programmes were suitable for use in Irish schools, and at which class level to implement them in. This evaluation was informed by the pilot study.

3.4.1 Comparison of the education systems in England & Wales and Ireland

In the educational system of England and Wales a child may begin formal education between the ages of 4 and 5 years. Primary school begins with the Reception year as part of the Early Years Foundation Stage (EYFS). Once a child has completed the reception year, they move into the first of 4 compulsory Key stages. Together, Key Stages 1 and 2 form the primary school system and Key Stages 3 and 4 form the second level. In England & Wales, children finish primary school at the end of Year 6, between the ages of 10 and 11 years. At the end of each Key Stage students sit the SAT's (Standard Assessment Tests) in English, Mathematics and Science. These exams are completed at the end of Years 2 and 6 in primary school, and Year 9 in secondary school. At the end of Key Stage 4, students sit the GCSE (General Certificate of Secondary Education) examinations. Following this, students have the option to further their studies by completing the two-year A-level programme which culminations in the A-level examinations.

In Ireland, children enter primary school between the ages of 4 and 5 years. Although there are formal literacy and numeracy tests, currently there is no formal assessment in science in the Irish primary education system. Children finish their primary school education at the end of 6th class, the equivalent of which is Year 7 in the educational system of England and Wales. Upon entry to second level education, students study a three-year course, which is marked to completion with the Junior Certificate examination. Students then have the option to complete Transition Year, or continue directly onto the last two years of school, which focuses on the Leaving Certificate course, concluding in a terminal examination at the end of 6th year. A comparison of the school systems can be seen in Figure 3.4.

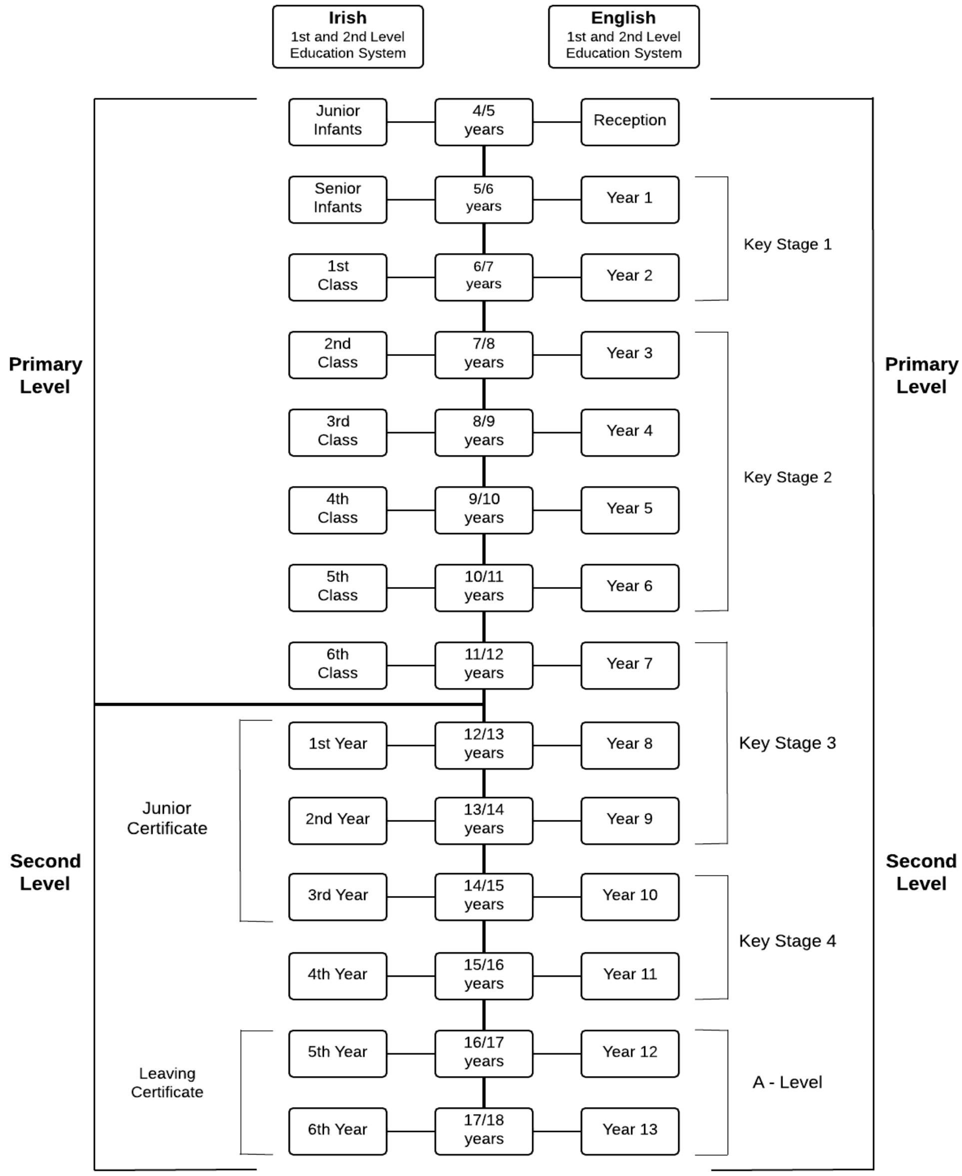

Figure 3.4: Main age and stage features of the educational systems of Ireland and England and Wales. Adapted from (McCormack. 2009)

3.4.2 Mapping the CASE activities onto the Irish curriculum

There are a total of five CASE programmes, each designed for a specific age group. The lessons are sequenced to provide a 'staircase' of development with each lesson focusing on one of the schema appropriate for that age level. The first time a schema is encountered it is aimed at a low level so that students are given the opportunity to become familiar with it and build up a sense of confidence. Each time the schema is met after this, it is more complex than in previous lessons. For example, there are two activities based on the schema of proportionality in the *Thinking Science!* programme. In order for students to comprehend the second lesson they must have completed the one that precedes it. Lessons are not grouped together according to their topic, nor are they grouped according to their schema. The development of one schema interacts and enhances the development of another. It is for this reason that it is advised not to hand pick lessons from the list because they fit with a certain topic, but to follow the sequence presented in the programme.

Table 3.8: Existing CASE programmes and their associated schema

	CASE programme	**Year Group**	**Classification**	**Seriation**	**Causality**	**Time Sequence**	**Spatial Perception**	**Rules of a game**	**Concrete Modelling**	**Combinatorial Thinking**	**Variables**	**Conservation**	**Listening**	**Proportionality**	**Inverse Proportionality**	**Probability**	**Correlation**	**Equilibrium**
1	Thinking Science	Year 7	X											X	X	X	X	X
2	Let's think through Science 8&9	Year 4 & Year 5	X						X		X	X	X					
3	Let's think through Science 7&8	Year 3	X						X	X	X	X	X					
4	Let's Think! 5&6	Year 1 & Year 2	X	X	X	X	X	X					X					
5	Let's Think! Early Years	Reception	X	X	X													

The lessons in each CASE programme were analysed individually and their suitability for the Irish curriculum and class level considered. Each lesson was analysed in relation to

- the age level at which they were aimed;
- their closeness-of-fit with the objectives of the Irish primary science curriculum;
- the development of the schema involved and;
- whether the lesson required specialized equipment.

In general, the CASE programmes were matched with the equivalent class grouping for which they were designed. Findings from the pilot study were used to inform the selection and adaption of existing CASE lessons. The original sequence was preserved where possible so as not to interfere with the development of the schemata. There are between 12 and 20 CASE lessons for each class level, developing a continuous programme of thinking through science for Irish primary schools. There is a large degree of overlap between the objectives of the primary science curriculum and the CASE lessons. All of the lessons overlap in some way with the objectives in the 'working scientifically' section of the curriculum as the lessons emphasise skills such as questioning, investigating, interpreting, analysing, recording and communicating. Although no scientific content is explicitly covered within the lessons, a number of lessons do link with the objectives in the curriculum in relation to scientific content. This is discussed in more detail within each class groups.

3.4.2.1 Sequence of lessons for the 5th and 6th class groups

The original CASE programme, *Thinking Science*, was developed as an intervention in the science curriculum of Year 7 and Year 8 students in England and Wales. The programme consists of 30 activities, each focusing on a different schema of formal operations, which can be seen in Table 3.9.

Table 3.9: The Thinking Science Third Edition activities and their associated reasoning pattern (denoted by ✓)

Lesson Number	*Thinking Science* Lesson	Variables	Classification	Proportionality	Inverse Proportionality	Probability	Combinations	Correlation	Formal Models	Equilibrium
1	What varies?	✓								
2	Two variables	✓								
3	What sort of relationship?	✓								
4	The 'fair' test	✓								
5	Rollerball	✓								
6	Making groups		✓							
7	More classifying		✓							
8	Gears and ratios			✓						
9	The wheelbarrow			✓						
10	Trunks and twigs				✓					
11	Keeping balanced				✓					
12	Current, length, thickness				✓					
13	Sampling Beans					✓				
14	Bean growth					✓				
15	Multiple choices						✓			
16	Interaction	✓								
17	Spinning coins					✓				
18	Tea tasting					✓				
19	The behaviour of woodlice							✓		
20	Treatments and Effects							✓		
21	Sampling: fish in a pond					✓				
22	Throwing dice					✓				
23	Explaining states of matter								✓	
24	Explaining solutions								✓	
25	Explaining chemical reactions								✓	
26	Pressure	✓								
27	Floating and sinking	✓								
28	Uphill and Downdale									✓
29	Divers	✓								
30	Re-balancing									✓

The cognitive demand of the *Thinking Science* lessons varies between mid concrete (2A/2B) to late formal operations (3A/B). The estimated operating range of the original lessons and their associated reasoning patterns are shown in Figure 3.5. The number in the circle represents the lesson number and can be referred to in Table 3.9. The main Piagetian level required for the lesson is shown on the left hand side of each of the figures, with the sequence of the lessons being indicated by their position on the chart from left to right. Both the range of difficulty of each lesson and the reasoning patterns are shown in Figure 3.5. The circle enclosing the lesson number indicates the Piagetian level at which most of the lesson is aimed at. The vertical line signifies the range estimated by Adey and Shayer (1994), from the minimum Piagetian level at which a student is likely to find the lesson profitable, to the upper level at which the lesson is designed to begin 'moving' the student (Adey & Shayer, 1994). The bulk of the lesson, including the concrete preparation phase, operates at a lower level, which should be accessible to 90 per cent of the class. When the cognitive conflict is introduced, the students are required to think at a higher operating level. The aim is that a significant cognitive demand is placed on each student, although all students may not reach the maximum level of the lesson. As the course develops, the level at which the lessons operate rises gradually. Wherever a new reasoning pattern is introduced explicitly for the first time, the 'entry level' of cognitive demand decreases. As the lessons proceed with the same reasoning pattern the level of cognitive demand increases.

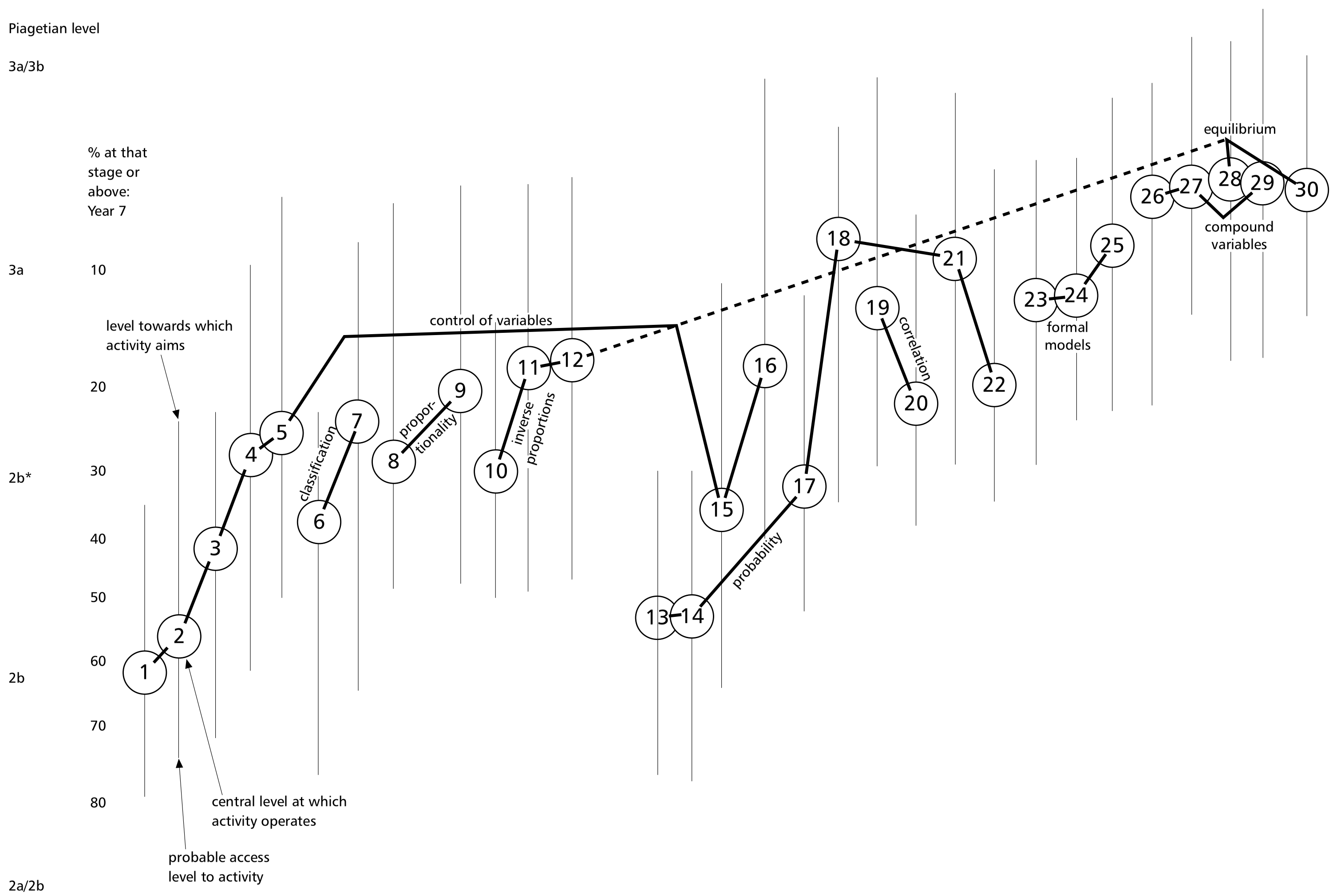

Figure 3.5: Estimated operating range of the Thinking Science lessons – Third Edition. (Taken from Adey *et al.*, 2003)

Careful consideration was given to the cognitive demand of the lesson when selecting which *Thinking Science* activities were suitable for use with 5th and 6th class students. The age of students in these year groups in Irish primary schools ranges from 10 to 12 years, which places them in the late concrete to early formal operational (2B-3A) stages. However, McCormack (2009) highlighted that a significant proportion of 6th class students were in the mid-late concrete stage (2A/2B), while very few were in the early formal stage (3A). It was decided to exclude any *Thinking Science* lessons which proceed above the early formal level as they may be too cognitively demanding for students in this group. While the aim of the *Thinking Science* activities is to create challenge for the students, this challenge should be aimed at an appropriate level so that the students do not become overwhelmed and frustrated. As a result, lessons 26, 28, 29 and 30 were omitted as they proceed above the early formal cognitive level and the cognitive structures required to resolve the conflict are greater than those available to the students. In addition, the resources required to implement the lesson were also taken into consideration. As the *Thinking Science* lessons were originally developed for use in secondary schools, some of the activities require specialized science equipment, which may not be available in primary schools. To facilitate the continuity of the CASE programme in primary schools after the research study had concluded, activities that required any specialized equipment were omitted. Activities 11, 12, 15, 16, 23, 24, and 25 were excluded for this reason.

The remaining activities were further divided into those suitable for 5th class and those suitable for 6th class, and are presented in Figure 3.6. Again the operating level and lesson sequencing was taken into account. Lessons 1-8 and 13–14 were considered appropriate for the 5th class programme as they generally operate at a lower level on the Piagetian scale. The remaining activities, which require more advanced thinking, were placed into the 6th class programme. However, activities 9 and 10 were also placed into the 6th class programme, which does not follow the sequencing of activities given in the original *Thinking Science!* programme. Lesson 9, *The Wheelbarrow,* which is the second lesson based on the schema of proportionality, is aimed at a higher operating level than that of activities 13 and 14, which were paced in the 5th class programme. Activities 13 and 14 are the first two lessons based on the schema of probability and therefore the cognitive demand is lower. Completing activities 13 and 14 before lesson 9, does not interfere with the development of either schema, and this reordering of activities was therefore considered acceptable. Lesson 27, *Floating and Sinking*, was also considered suitable to implement with the 6th class students. Although the main part of this lesson proceeds above the early formal operational level, the topic of floating and sinking features heavily in the Irish primary science curriculum. The beginning of the lesson requires students to devise a fair test, which students have previously completed in lesson 4 (*The Fair Test)* and lesson5 (*Rollerball)*. The later part of the lesson requires students to comprehend the concept of density and, while all students may not reach the maximum level of the lesson, they may be aware that whether a jar floats or sinks depends on more than volume or weight alone. For these reasons, it was decided to include this lesson in the 6th class programme.

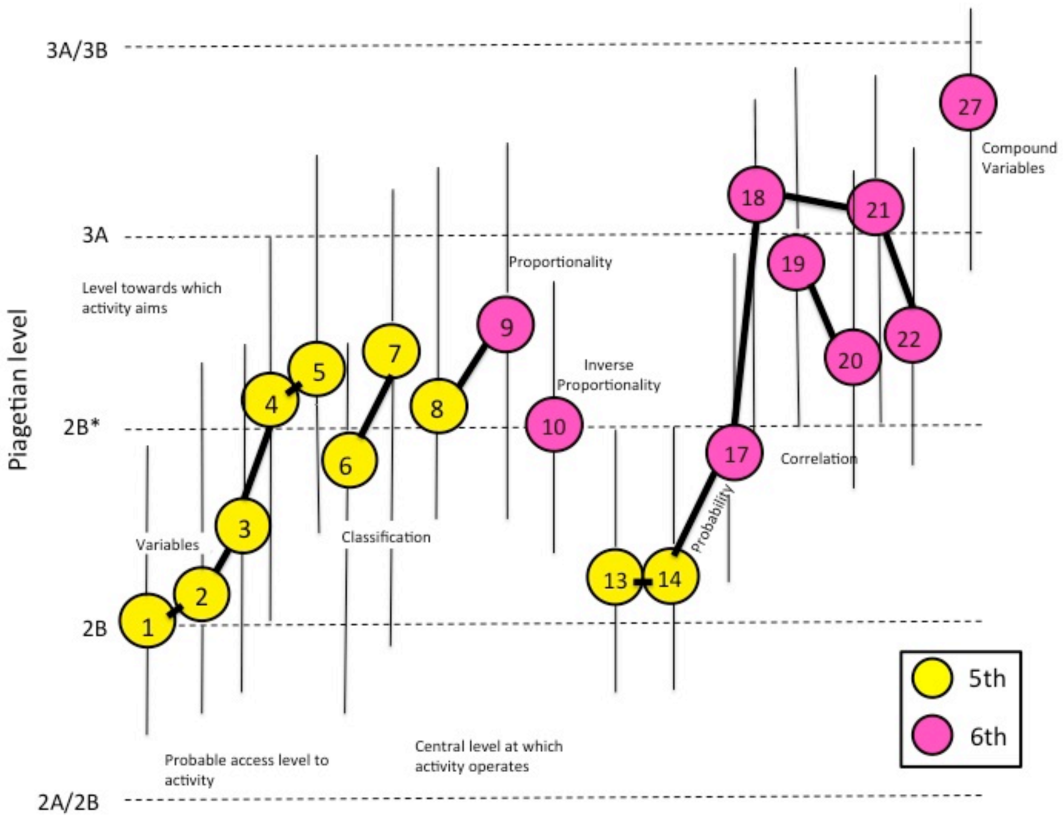

Figure 3.6 Estimated operating range of the CASE activities considered suitable for fifth and sixth class. Lesson numbers correspond to the lessons in Table 3.9.

Further adaptions were made to the CASE activities, which are listed below.

i. Extra Science Content

The *Thinking Science* programme was initially designed for use in secondary schools and would therefore be delivered by subject-specific science teachers. One of the main differences between primary and second level education is the previous education and training of teachers in science. Many primary level teachers have not studied science since their school days and yet are required 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, necessary apparatus, procedure summary and a detailed lesson plan. The introduction provided information on the main purpose and points of the lesson. However, the lesson plans often lack the scientific background information required by teachers at primary level to implement them successfully. McCormack (2009) adapted the original CASE lessons to provide teachers with additional scientific detail on the topic of the lesson or the schema involved. This was intended to cut down on extra time that may have been spent by teachers sourcing information and researching additional material on the content, to instil confidence in non-specialised teachers and to make them feel more adequately prepared for the lesson. These adapted lessons were considered suitable for use in this study and can be found in Appendix H.

ii. Lessons Format

In addition to supplementary scientific content knowledge, the original *Thinking Science* lesson plans were adapted to follow the same format as the CASE programmes developed for use in primary schools. Lessons in the *Let's Think!* and *Let's Think Through Science!* programmes (4 to 9 years) are written in great detail under the headings of the main pillars. Suggested questions and dialogue between teacher and pupil is printed in bold in the lesson plan for the teachers to follow. Questions designed to provoke metacognitive thought are also part of the lesson plan. While strategies to help teachers guide their students through the main pillars are discussed in the *Thinking Science* lessons, there are no recommended questions to ask, or script to follow. The 6th class teacher in the pilot study found the lesson layout overwhelming and, as a result, the lessons were adapted to follow the same format as those in the *Let's Think!* and *Let's Think Through Science!* programmes.

iii. Lessons shortened

A further outcome of the pilot study was that a small number of the *Thinking Science* activities were considered too long for use in primary school. T29 often felt that the lessons were being rushed and, as a result, the pillar of metacognition was often omitted. Lessons *What sort of relationship?, Rollerball* and *Spinning Coins* were each divided into two separate activities, with each lesson having an episode of cognitive conflict, social construction and metacognition. It was hoped that this would offer sufficient time to complete all aspects of the lesson while also creating appropriate cognitive challenge for the students.

The complete set of lessons considered suitable for use in the 5th and 6th classes can be seen in Table 3.10. Additional cognitive acceleration activities, '*Fat in Crisps*' and '*The Germination Challenge*', developed by McCormack (2009), were also considered suitable for this age level and were added to the 6th class programme, so that each class group has a total of 12 cognitive acceleration lessons.

Table 3.10: Sequence of lessons for 5th and 6th class

5th Class			6th Class		
	Lesson	**Schema**		**Lesson**	**Schema**
1	What Varies	Variables	**1**	The Wheelbarrow	Proportionality
2	Two Variables	Variables	**2**	Trunks and Twigs	Inverse Proportionality
3	What sort of relationship? 1	Variables	**3**	Spinning Coins 1	Probability
4	What sort of relationship? 2	Variables	**4**	Spinning Coins 2	Probability
5	The 'Fair' Test	Variables	**5**	Tea Tasting	Probability
6	Rollerball 1	Variables	**6**	Behaviour of Woodlice	Correlation
7	Rollerball 2	Variables	**7**	Treatments and Effects	Correlation
8	Making Groups	Classification	**8**	Sampling-Fish in a Pond	Probability
9	More Classifying	Classification	**9**	Throwing Dice	Probability
10	Gears and Ratio	Proportionality	**10**	Floating and Sinking	Compound Variables
11	Sampling Beans	Probability	**11**	Fat in Crisps	Proportionality
12	Bean Growth	Probability	**12**	Germination Challenge	Fair Test

The objectives of the CASE lessons shown in Table 3.10 were compared with the objectives specified in the Irish primary science curriculum for the 5th and 6th class groups. There is a large degree of overlap between the objectives of the curriculum and the CASE lessons, particularly in relation to the development of scientific skills, as shown in Tables 3.11 and 3.12. Lessons that incorporate the schema of probability overlap with the maths curriculum in relation to content, however, by engaging in these lessons, students also develop their scientific skills, such as questioning, analysing, recording and communicating.

Table 3.11: Comparison of the lessons for the 5th class and the Irish primary science curriculum objectives

Lesson No.	*Thinking Science!* Lesson	Schema	Strand Unit/ Skill	Objective
1	What Varies?	Variables	Working Scientifically	Look for and recognise patterns and relationships when making observations
2	Two Variables	Variables	Working Scientifically	Look for and recognise patterns and relationships when making observations
3	What sort of Relationship? 1	Variables	Working Scientifically	Look for and recognise patterns and relationships when making observations
4	What sort of Relationship? 2	Variables	Working Scientifically	Look for and recognise patterns and relationships when making observations
5	The Fair Test	Control of Variables	Working Scientifically	Realize that an experiment is unfair if relevant variables are not controlled
6	Roller Ball 1	Control of Variables	Working Scientifically	Realize that an experiment is unfair if relevant variables are not controlled
7	Roller Ball 2	Control of Variables	Working Scientifically	Design, plan and carry out simple experiments, having regard to one or two variables and their control
8	Making Groups	Classification	Working Scientifically	Sort and represent data in sets and sub-sets
9	More Classifying (Birds)	Classification	Working Scientifically	To group and compare living things into sets according to their similarities and differences
10	Gears and Ratios	Proportionality	Maths (Length)	Use and interpret scales
11	Sampling Beans	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
12	Bean Growth	Probability	Plants and Animals	To investigate the factors that affect plant growth

Table 3.12: Comparison of the lessons for the 6th class and the Irish primary science curriculum objectives

Lesson No.	*Thinking Science!* Lesson	Schema	Strand Unit/ Skill	Objective
1	The Wheelbarrow	Proportionality	Forces	To explore how levers may be used to help lift different objects
2	Trunks and Twigs	Proportionality	Working Scientifically	Interpreting - Draw conclusions from suitable aspects of the evidence collected
3	Spinning coins 1	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
4	Spinning coins 2	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
5	Tea Tasting	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
6	The Behaviour of Woodlice	Correlation	Plant and animal Life	To observe and explore some ways in which animal life is influenced by environmental conditions
7	Treatment and Effects	Correlation	Working Scientifically	Interpreting - Draw conclusions from suitable aspects of the evidence collected
8	Sampling-fish in a pond	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
9	Throwing Dice	Probability	Maths (Chance)	To estimate the likelihood of occurrence of events
10	Floating and sinking	Compound Variable	Working Scientifically	Design, plan and carry out simple experiments, having regard to one or two variables and their control
11	Fat in Crisps	Proportionality	Human Life	To develop a simple understanding of food
12	Germination Challenge	Fair Test	Plant and Animal Life	To investigate the factors that affect plant growth

3.4.2.2 Sequence of lessons for the 3rd and 4th class groups

The *Let's think through Science! 8&9* programme was designed for use with students aged between 8 and 9 years. This age group corresponds to the 3rd and 4th class groups in the Irish educational system. The programme consists of 18 CASE activities, and a further two introductory activities. The activities have an increased focus on subject matter and are divided into topics such as movement, habitats, heat, forces and electricity. There is a large degree of overlap between the content covered in these activities and the objectives laid out in the Irish science curriculum for the 3rd and 4th class groups as shown in Table 3.13. For use in the Irish education system, the activities were divided into two separate programmes for the 3rd and 4th classes, and the original sequence of activities was preserved. Some of the activities require additional resources, however, these are common materials that are easily sourced therefore none of the lessons were excluded in this group.

Table 3.13: Comparison of the lessons for the 3rd and 4th class and the Irish primary science curriculum objectives

Lesson No.	*LLTS 8&9* Lesson	Schema	Strand Unit/ Skill	Objective
1	Climb that mountain	Introductory Activity	Working Scientifically	Interpret information and offer explanations
2	Make that Box	Introductory Activity	Design and make	Planning, making, evaluating
3	Who am I?	Classification	Human Life/Plant and animal life	Diversity in human and animal skeletons
4	All these Bones	Classification/ Seriation	Human Life	Identify different human bones and their function
5	What makes me move?	Concrete Modelling	Human Life	Investigate how people move (bones/joints)
6	Where do I live?	Classification	Plant and Animal life	Investigate plants and animals that live in local and wider environments
7	How am I Adapted?	Causality	Plant and Animal life	Observe and explore ways in which plants and animals are adapted to their environments
8	What am I?	Causality	Plant and Animal life	Observe and explore ways in which plants and animals are adapted to their environments
9	How Hot are You?	Classification	Heat	Thinking about the temperatures of ordinary objects
10	Hotter or Colder?	Variables	Heat	Learn that heat can be transferred
11	I Like my Soup Hot	Seriation	Heat	Measure changes in temperature
12	Where does it belong	Classification	Properties of materials	Recognise that materials can be solid liquids or gas. Group materials according to their properties
13	I can't find the Sugar	Conservation	Materials and change	Investigate how materials may be changed by mixing.
14	Sorting out the mix-ups	Concrete Modelling	Materials and change	Explore some simple ways in which materials may be separated
15	Where are the forces?	Causality	Forces	Explore how objects can be moved
16	Can you change the force?	Causality	Forces	Explore the relationship between movement and the amount of force that is exerted on the object
17	Late for School	Variables	Forces	Friction of the wind
18	My bulb won't work	Concrete Modelling	Magnetism and Electricity	Investigating current electricity by constructing simple circuits
19	Do I work?	Classification	Magnetism and Electricity	Investigating current electricity by constructing simple circuits
20	Controlling the Light	Causality	Magnetism and Electricity	Investigating current electricity by constructing simple circuits

An outcome of the pilot programme indicated that the lessons at this level were too 'paper-based' and did not allow the students to engage in any practical scientific work. As a result, lessons *I like my soup hot* and *Do I work?* were divided into two separate CASE activities to incorporate a practical element, while still focusing on the cognitive acceleration methodology. Four additional lessons on the topic of forces were developed (*Bungee, Falling, Parachutes, Friction*) and added to the existing programme. These lessons are based on the pillars of the cognitive acceleration methodology, and focus on the schema of control of variables. The adapted lessons and additional lessons developed can be found in Appendix H. In keeping with the format of the existing CASE programme, the first time the students are introduced to the concept of controlling variables, it is at a low level and should be accessible to most of the students. As the sequence of lessons progresses, the tasks become increasingly more difficult. The complete set of lessons for the 3rd and 4th class groups can be see in Table 3.14.

Table 3.14: CASE lessons considered suitable for 3rd and 4th class

3rd Class			**4th Class**		
	Lesson	**Schema**		**Lesson**	**Schema**
1	Climb that Mountain	Introductory	**1**	Make that Box	Introductory
2	Who am I?	Classification	**2**	Where are the forces?	Causality
3	All these Bones	Classification	**3**	Can you change the force?	Causality
4	What makes me Move?	Concrete Modelling	**4**	Bungee	Variables/Fair Test
5	Where do I Live?	Classification	**5**	Falling	Variables/Fair Test
6	How am I Adapted?	Causality	**6**	Late for School	Relationships
7	What am I?	Causality	**7**	Parachutes	Variables/Fair Test
8	Who hot are you?	Classification	**8**	Friction	Variables/Fair Test
9	Hotter or Colder?	Relationships	**9**	My bulb won't work	Concrete Modelling
10	I like my Tea Hot (a)	Seriation/Fair Test	**10**	Do I work? (a)	Classification
11	I like my Tea Hot (b)	Seriation/Fair Test	**11**	Do I work? (b)	Classification
12	Where does it belong?	Classification	**12**	Controlling the light	Causality
13	I can't find the Sugar	Conservation			
14	Sorting out the mix-ups	Concrete Modelling			

3.4.2.3 Sequence of lessons for the 2nd class group

The *Let's think through Science! 7&8* programme consists of 17 activities, including two introductory activities, focusing on the schemata of concrete operations. The lessons were designed for use with students between the ages of 7 and 8 years, which corresponds to the 2nd class group in the Irish educational system. Again, the lessons were analysed and compared with the objectives in the Irish science curriculum. Table 3.15 highlights that there is a large degree of overlap between the content covered in these lessons and the objectives laid out in the Irish science curriculum for the 2nd class group. Again, the lessons do not require any specific science equipment hence no lessons were omitted for this reason. The existing *Let's think through Science! 7&8* programme was therefore considered suitable to implement with 2nd class group and no adaptions were made.

Table 3.15: Comparison of the lessons for the 2nd class and the Irish primary science curriculum objectives

Lesson No.	*Let's Think through Science 7&8* Lesson	Schema	Strand Unit/ Skill	Objective
1	Money matters	Introductory Activity	Working Scientifically/ Money (Maths)	Analysing/ Problem solving
2	Painted doors	Introductory Activity	Working Scientifically	Analysing
3	Grouping foods	Classification	Human Life	To develop an awareness of the importance of food for energy and growth
4	Animals and teeth	Causality	Human Life	To develop an awareness of the importance of food for energy and growth
5	Sandwiches	Combinatorial Thinking	Working Scientifically	Analysing/ Problem solving
6	Are they seeds?	Classification	Plant and Animal Life	To explore, through the growing of seeds, the need of plants for water and heat
7	Clothes to wear	Variables	Materials and Change	To investigate the suitability of different kinds of clothes for different temperatures
8	Classifying materials	Classification/ Variables	Properties of materials	To group materials according to their properties
9	Classification of rocks	Classification	Properties of materials	To describe and compare materials, noting differences in colour, shape and texture
10	Composition of Soils	Concrete Modelling	Materials and Change	To investigate how materials may be changed by mixing
11	Sorting magnetic materials	Classification	Magnetism	Examine and classify materials as magnetic and non-magnetic
12	Strength of magnets	Variables	Magnetism	(Large magnets are not always the strongest)
13	Exploring Poles	Concrete Modelling	Magnetism	To explore magnetic poles and investigate how the attract and repel each other
14	Potatoes	Causality	Forces	(Heavier objects have a greater downward force)
15	Shadow Stick	Causality	Light	(Light travels in straight lines)
16	Make a Shadow Puppet	Causality	Design and make	Planning, making, evaluating
17	Conservation of Volume	Conservation	Capacity (Maths)	Fill several containers using the same unit and arrange in order of capacity; discuss

3.4.2.4 Sequence of lessons for the Junior Infants, Senior Infants and 1st class groups

The *Let's Think! Early Years* (Robertson, 2006) programme consists of 15 activities aimed at developing the thinking abilities students between the ages of 4 and 5 years. The activities were designed to fit in any early years curriculum. Each lesson is based on one of the three main schema of the pre-operational child, namely classification, seriation and causality. The activities were primarily designed to develop children's thinking, but to also develop their speaking and listening skills, their collaborative work with others and their understanding about how best they may learn.

The *Let's Think!* 5&6 programme (Adey *et al., 2001)* was developed to use with five and six year old students. The programme consists of 30 activities, including 3 introductory activities, which are designed to begin moving students from pre-operational to concrete operational thought. Ideally, the lessons in both the *Let's Think Early Years* and *Let's Think! 5&6* programmes are carried out with small groups of 4 or 5 students at a time giving the teacher the opportunity to work closely with the students and facilitate the lesson more effectively. For use in this study, the *Let's Think Early Years* programme was considered suitable for use in Junior Infants. while the *Let's Think! 5&6* programme was considered suitable for use in Senior Infants and 1st class. The first half of the programme to be completed in Senior Infants, followed by the second half of the programme in 1st class. The sequence of lessons was preserved so as not to interfere with the development of the schema. The complete set of lessons for each class level is shown in Tables 3.16 and 3.17.

Table 3.16: CASE lessons considered suitable for Junior Infants

Junior Infants		
	Lesson	**Schema**
1	Colourful Flowers	Classification/Seriation
2	Where do I live?	Classification
3	What do I eat?	Classification
4	My Senses	Classification
5	Castles at the seaside	Seriation
6	At the seaside	Classification
7	Mixed-up stories	Seriation/Classification
8	Where are my toys?	Classification
9	How do my toys move?	Causality
10	Holes	Causality
11	Who are we?	Seriation
12	Sort us out	Classification
13	Enjoying ourselves	Classification
14	Our Birthdays	Classification
15	We watch TV	Classification

Table 3.17: CASE lessons considered suitable for Senior Infants and 1st Class

Senior Infants			First Class		
	Lesson	**Schema**		**Lesson**	**Schema**
1	Clown Faces	Listening	**1**	Living	Classification
2	Space	Listening	**2**	Guess What?	Classification
3	Animals	Listening	**3**	Library Books	Seriation
4	Sticks	Seriation	**4**	Crossroads I	Spatial Perception
5	Flowers	Seriation	**5**	Looking at Shapes	Spatial Perception
6	Marble Run	Seriation	**6**	Crossroads II	Spatial Perception
7	Sorting Shapes	Classification	**7**	Bricks	Classification
8	Farm Animals 1	Classification	**8**	Rolling Bottles	Causality
9	Buttons	Classification	**9**	The Cat and the Snail	Time Sequence
10	Farm Animals 2	Classification	**10**	Shadows	Causality
11	Lost Boot	Time Sequence	**11**	In this Town	Rules of a game
12	Cars	Classification	**12**	Making a Game	Rules of a game
13	Stones	Seriation	**13**	Transformations	Causality
14	Boxes	Seriation	**14**	Farmyard	Spatial Perception
15	Cooking	Time Sequence	**15**	The Ice Cream Story	Time Sequence

The lessons were analysed and compared with the objectives presented in the primary science curriculum in relation to content and scientific skill development. In general, there is some overlap between the content covered in the CASE activities and the objectives in the primary science curriculum as shown in Tables 3.16 and 3.17. However, some activities do not directly match with science curriculum objectives in relation to scientific content. While activities in both programmes cover some science topics, their primary aim is the development of students' thinking, rather than on increasing their scientific content knowledge. Activities that do not directly overlap with science curriculum objectives in relation to content do match with the objectives in relation to developing students' scientific skills such as questioning, observing and analysing. There is also a degree of overlap with the objectives of the Maths curriculum, particularly in relation to spatial awareness and time sequencing.

Table 3.18: Comparison of the lessons for the Junior Infants and the Irish primary science curriculum objectives

Lesson No.	*Let's Think! Early Years* Lesson	Schema	Strand Unit/ Skill	Objective
1	Colourful Flowers	Classification/ Seriation	Light	Identify and name different colours Sort objects into sets according to colour
2	Where do I live?	Classification	Plants and Animals	Observe, discuss and identify a variety of plants and animals in different habitats
3	What do I eat?	Classification	Plants and Animals	Observe, discuss and identify a variety of plants and animals in different habitats
4	My Senses	Classification	Myself	My Senses
5	Castles at the seaside	Seriation	Working Scientifically	Order objects according to length or height
6	At the seaside	Classification	Plants and Animals	Observe, discuss and identify a variety of plants and animals in different habitats
7	Mixed-up stories	Seriation/ Classification	Maths (Time)	Sequence daily events or stages in a story
8	Where are my toys?	Classification	Working Scientifically	Questioning/Interpreting
9	How do my toys move?	Causality	Working Scientifically	Questioning/Interpreting
10	Holes	Causality	Properties of Materials	Investigate materials for different properties
11	Who are we?	Seriation	Myself	To recognise and measure physical similarities and differences between people
12	Sort us out	Classification	Myself	To recognise and measure physical similarities and differences between people
13	Enjoying ourselves	Classification	Myself	Classify objects on the basis of one attribute
14	Our Birthdays	Classification	Myself	Classify objects on the basis of one attribute
15	We watch TV	Classification	Myself	Classify objects on the basis of one attribute

Table 3.19: Comparison of the lessons for the Senior Infants and 1st class and the Irish primary science curriculum objectives

Lesson No.	*Let's Think! 5&6* Lesson	Schema	Strand Unit/ Skill	Objective
1	Clown Faces	Listening	All	-
2	Space	Listening	All	-
3	Animals	Listening	All	-
4	Sticks	Seriation	Comparing and Ordering (Maths)	Order sets of objects
5	Flowers	Seriation	Comparing and Ordering (Maths)	Order sets of objects
6	Marble Run	Seriation	Comparing and Ordering (Maths)	Order sets of objects
7	Sorting Shapes	Classification	Properties of Materials	Group materials according to certain criteria
8	Farm Animals 1	Classification	Plants and Animals	Sort and group living things into sets
9	Buttons	Classification	Properties of Materials	Group materials according to certain criteria
10	Farm Animals 2	Classification	Plants and Animals	Sort and group living things into sets
11	Lost Boot	Time Sequence	Time (Maths)	Use the vocabulary of time to sequence events
12	Cars	Classification	Properties of Materials	Group materials according to certain criteria
13	Stones	Seriation	Properties of Materials	Group materials according to certain criteria
14	Boxes	Seriation	Comparing and Ordering (Maths)	Order sets of objects
15	Cooking	Time Sequence	Time (Maths)	Use the vocabulary of time to sequence events
16	Living?	Classification	Plants and Animals	Sort and group living things into sets
17	Guess What?	Classification	Working Scientifically	Questioning/Interpreting/ Communicating
18	Library Books	Seriation	Comparing and Ordering (Maths)	Order sets of objects
19	Crossroads I	Spatial Perception	Spatial Awareness (Maths)	Explore, discuss, develop and use the vocab of spatial awareness
20	Looking at Shapes	Spatial Perception	Spatial Awareness (Maths)	Explore, discuss, develop and use the vocab of spatial awareness
21	Crossroads II	Spatial Perception	Spatial Awareness (Maths)	Explore, discuss, develop and use the vocab of spatial awareness
22	Bricks	Classification	Working Scientifically	Analysing/ Interpreting
23	Rolling Bottles	Causality	Working Scientifically	Analysing/Interpreting
24	The Cat and the Snail	Time Sequence	Time (Maths)	Use the vocabulary of time to sequence events
25	Shadows	Causality	Light	Investigating the relationship between light and materials
26	In this Town	Rules of a Game	Working Scientifically	Questioning/ Observing/ Communicating
27	Making a Game	Rules of a Game	Design and making	Plan,/make/ evaluate
28	Transformations	Causality	Working Scientifically	Questioning/Interpreting/ Communicating
29	Farmyard	Spatial Perception	Spatial Awareness (Maths)	Explore, discuss, develop and use the vocab of spatial awareness
30	The Ice Cream Story	Time Sequence	Time (Maths)	Use the vocabulary of time to sequence events

Overall, the CASE lessons (with adaptions) appear suitable for use in Irish primary schools. There is a large degree of overlap between the CASE lessons and the objectives in the curriculum, in relation to the development of students' scientific content knowledge and skills. Although developing student's content knowledge is not the main aim of lessons, it is reasonable to assume that schools and teachers are more likely to incorporate the CASE lessons into their teaching if they overlap with curriculum objectives. The CASE lessons also fit with the aims of the primary curriculum, that students should construct knowledge for themselves, be able to transfer and apply their thinking to other areas and to develop as independent thinkers and learners.

3.5 Whole School Implementation

Following the pilot study, the principal and teaching staff opted to expand the implementation of the CASE methodology to include all class levels in the school. This phase of the study lasted for 1 year and involved all 31 class teachers from Junior Infants to 6th class. The principal was supportive of the study and wanted to create a continuous programme of thinking science throughout the school. The principal allocated sufficient time so that the teachers could participate in focus group discussions and designated a 'science room' where the CASE lessons could be held. This room was arranged to facilitate group and investigative activities and allowed the teachers to focus on their implementation of the lessons. Only a limited amount of time was available to prepare the teachers to implement the CASE lessons and the programme implemented was designed to contend with this. The programme design was informed by the pilot study and included features of the original CASE professional development such as:

- Focus on the underlying theory of the CASE methodology,
- Collective participation,
- In-class coaching and,
- Reflection on practice.

The programme aimed to provide the teachers with a sound understanding of the CASE methodology and assist the teachers in developing the skills needed to foster higher-order thinking in their students.

For this phase of the study, the eight class levels were divided into 5 groups, as shown in Table 3.20. All of the groups (excluding the 2nd class group) included a teacher who participated in the pilot study. The pilot study teachers generally had positive attitudes towards the methodology and could share their experiences with the other teachers. In order to aid the teachers with their implementation of the lessons, the school was provided with all of the materials required. These were prepared in a ready-to-use fashion, to eliminate material preparation time, giving teachers more time to prepare for the delivery aspects of the class.

Table 3.20: Grouping of teachers during the whole-school implementation phase of the study

Class group	No. of teachers	Pilot Teacher
5th and 6th	7	T29
3rd and 4th	8	T24
2nd	4	-
Senior Infants and 1st Class	8	T12
Junior Infants	4	T2

The evaluation of the pilot study highlighted that the teachers were unfamiliar with the CASE methodology at the end of the programme. It is reasonable to assume that a sound knowledge of the underling theory will assist the teachers in their implementation of the lessons. Therefore, during the whole-school implementation phase, an increased emphasis was placed on developing the teachers' knowledge and understanding of the CASE methodology. Furthermore, teachers in primary school frequently move class level and there is no guarantee that they will be teaching the same class level next year. Developing a deeper understanding of the theory behind CASE, and strategies for successful implementation, may facilitate teachers in their implementation of the lessons at other class levels, and support the continuity of the CASE programme once the study has concluded.

To facilitate this in-depth analysis of the methodology, the teachers participated in regular focus group meetings throughout the programme. These were conducted within the class groups shown in Table 3.20, as topics to be taught, teaching strategies required, and other practicalities were often specific to each class level. During focus group meetings, the teachers were introduced to the CASE lessons to be taught in sets of three. This allowed for a more in-depth analysis of each lesson, the specific teaching strategies required and the science content covered. It was hoped that this would prevent the teachers from feeling overwhelmed by a large amount of new material, as was observed in the pilot study. Teachers at primary level are also non-specialised teachers and may not have a complete understanding of the science content covered in the lessons. Although the primary focus of the CASE lessons is on the schemata involved and in creating a culture of thinking and reasoning, it is reasonable to assume that a lesson will run more smoothly if the teacher also has a deeper understanding of the science content involved in the lesson.

- **Focus group meetings**

The main aim of the initial focus group discussions was to immerse the teachers in the underlying theory of CASE in so far as possible. The teachers were introduced to the CASE methodology, the schemata involved and strategies to guide the students through the pillars. Each teacher was also provided with a folder containing all of the lessons, further information on cognitive development and the schemata for each class level, background information of the CASE methodology and a brief overview of some relevant results of the CASE intervention. General strategies to successfully navigate students through each pillar were also included. An overview of the plan for the year was discussed, and the teachers were given the opportunity to ask questions and to make suggestions. The first three CASE lessons to be taught, and strategies for successful implementation, were discussed in detail with the teachers. The teachers engaged with the lessons from a teacher's perspective, considering suitable approaches to implement the lesson in their classroom. The pilot study teachers shared their experience of the CASE lessons with the other teachers, and suggested methods to guide the students through the pillars of the lessons.

Subsequent focus group meetings were held every six weeks and lasted between 45minutes to 1 hour. These meetings provided the teachers, and the researcher, with the opportunity to give regular feedback on the progress of the programme, and to address any concerns that the teachers might have had. The teachers reflected on, and evaluated their implementation of the previous three lessons and identified areas of success and aspects that they felt they needed further support in developing. The researchers' observations were used to inform these discussions and offer suggestions to the teachers on a group basis. The teachers collaborated and shared strategies for implementing the CASE methodology in general, and strategies specific to each lesson. The theory of the CASE methodology was often revisited during focus groups as a way of supporting teachers with their implementation. The teachers were also introduced to the next three lessons to be taught and discussed approaches to implement the activities in their classrooms. It was hoped that this sharing of ideas and supporting one another in their implementation would develop a sense of collegiality amongst the teachers. Collaboration amongst teachers is considered an important factor in the effectiveness of a professional development programme (Penuel, 2007; Guskey, 2003; Garet *et al*., 2001). As this study involved the whole school, it also gave the teachers an opportunity to discuss the methodology with teachers from other class levels in an informal setting such as the staff room. Discussions between teachers of different class levels could focus beyond the practicalities of the lesson, and concentrate on the theory behind the methodology, and how to apply that theory in the classroom

- **Coaching/Observations**

Teachers engaged in numerous episodes of coaching and/or team teaching throughout the programme. The researcher observed every second lesson implemented by the teachers. This framework allowed each teacher to attain regular feedback on their implementation of the lessons. During team teaching, the teacher retained overall control of the class, with the researcher facilitating the lesson and interjecting when requested. The pilot study highlighted that the teachers gained very little from observing the researcher implementing the lessons. Therefore, during the main phase of the study, team-teaching with the researcher was preferred when teachers highlighted an aspect of the CASE lessons that they found difficult. This allowed the teachers to see possible strategies to overcome these issues and transfer observed skills to their own practices. However, only the teachers of 2nd to 6th class engaged in coaching or team teaching on a regular basis. This was due to the nature of the Junior Infants to 1st class programmes, where the teacher implemented the same lesson with a different group of students each day. Teachers often did not teach the lesson at the same time everyday, which made arranging a time for coaching difficult. Teachers in these classes were observed teaching the CASE lessons at least once during the year, and offered feedback afterwards. The teachers' progress and any difficulties encountered were discussed during focus group interviews. During coaching/observations, the researcher used an observation scale to rate the teachers implementation of a number of aspects of the lesson. This is discussed in more detail in Chapter 4.

- **Reflection on practice**

According to the 'Code of Professional Conduct for Teachers' (Teaching Council, 2012), reflection on practice is a requirement for all teachers to sustain and improve the quality of their professional practice. Teachers should "*reflect on and critically evaluate their professional practice, in the light of their professional knowledge base*" (Teaching Council, 2012 p.8). The teachers in this study were encouraged to reflect on their implementation of the CASE lessons in a number of ways:

- In individual discussions with the researcher,
- In focus group discussions and,
- In written lesson reflections.

Teachers were encouraged to reflect on their practice so that they could identify aspects of the lessons that they found difficult and become conscious of their progress. To bring about change, reflective conversations should not only review what was thought and done, but also consider what might be improved (Ghaye & Ghaye, 1998). The teachers reflected on their implementation as a group during focus group discussions with the aim of promoting a sense of belonging and sustaining the implementation of the CASE methodology once this study had ended. The teachers were also asked to individually reflect on their implementation of each lesson by completing a written lesson reflection (Appendix F). The teachers' responses to the lesson reflections were used to evaluate the teachers' success in implementing the CASE lessons. The analysis of the lesson reflections is discussed in more detail in Chapter 4.

The whole-school implementation phase of the research was designed to be intense, involving approximately 30 hours engagement with the CASE methodology for each teacher. This includes focus group meetings, coaching sessions and implementing the activities. Teachers were given multiple opportunities to engage with, and practice their new pedagogies and assimilate the new methods into their teaching. The hours of engagement were slightly less for the teachers of Junior Infants who did not begin implementing the activities until the beginning of the second term. On average, teachers from 2^{nd} – 6^{th} class participated in between 3 and 7 coaching sessions each. A general outline of the programme structure is shown in Figure 3.7. The main features of the programme included:

- One lesson delivered every two weeks;
- Teachers completed a written lesson reflection after each lesson;
- Every second lesson observed by researcher;
- Regular focus group meetings after every three lessons i.e. every six weeks.

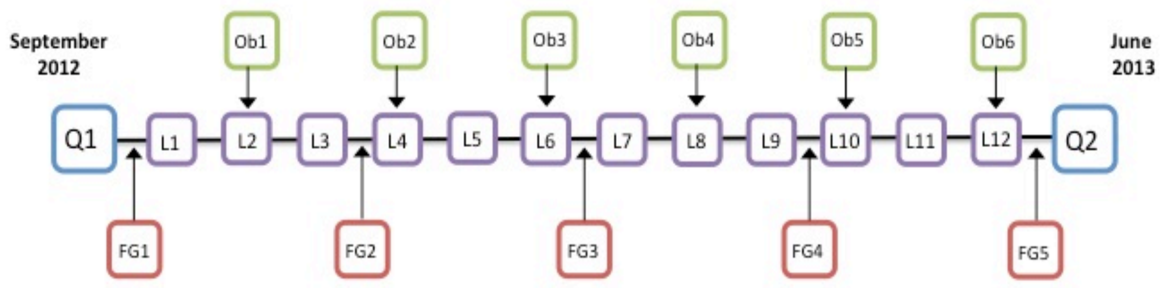

Figure 3.7: General outline of programme design for the whole-school implementation phase of the study. (FG= Focus group, L = Lesson, O = Observation, Q = Questionnaire)

However, the number of lessons implemented/focus groups held, varied for each class group and is discussed in more detail in Chapter 6. The aim of this programme design was to provide the teachers with an adequate knowledge of the CASE methodology and opportunities to develop their skills so that they could successfully guide their students through the pillars of the lessons.

This chapter has provided an overview of the research method of this study, including evaluating the pilot study and its' implications for the whole-school implementation, adapting the existing CASE programmes for use in the Irish educational system and mapping the lesson objectives onto curriculum. Data collection methods and the programme design for the main phase of the study were also described. The next chapter discusses the analysis of the data collection methods outlined in Section 3.2.

Chapter 4

Analysis of Data Sources

Introduction

This chapter describes the analysis of the data collected in the whole-school implementation phase of the study. Data collection methods include questionnaires, individual teacher reflections and researcher observations. The chapter is divided into three sections. The first section (4.1) describes the analysis of the teachers' responses to the written Lesson Reflections. A scale was applied to the teachers' responses, which was used to generate an overall measure of the teachers' confidence and success in implementing each CASE lesson. The second section (4.2) describes the observation rubric used by the researcher during the whole-school implementation phase of the study. The final section (4.3) discusses the underlying theory of multi-dimensional scaling and its' application in this study.

4.1 Lesson Refection Analysis

The teachers were asked to complete a written Lesson Reflection after every lesson. The 18-item reflection consisted of open, closed and Likert style questions that encouraged the teachers to reflect on their implementation of the lessons (Appendix F). The teachers were asked to describe their implementation of each pillar of the lesson and rate how successful they felt their implementation was on a numerical scale. The Lesson Reflections were then analysed and used to obtain a measure of the teachers' confidence and success in implementing each lesson. The teachers' responses to the Lesson Reflections can be found in Appendix I on the attached disc.

a) Confidence

A number of items in the Lesson Reflections required the teachers to rate their confidence in how successful they felt their implementation of specific aspects of the lesson was. These items were Likert-scale questions on a scale of 1-5, with 1 being completely unsuccessful, and 5 being very successful. The questions from the Lesson Reflections included in this analysis were:

Q3	*Overall, how successful do you think the lesson was?*
Q5	*How successful was your introduction to the lesson?*
Q9	*How successful were you at guiding the students through the cognitive conflict/class discussion stage?*
Q12	*How successful were you at not telling the students the answer?*
Q14	*How successful were you at getting the students to think about their thinking after the lesson?*

Question 5 refers to the pillar of concrete preparation, question 9 refers to the pillars cognitive conflict and social construction and question 14 refers to the pillar of metacognition. The teachers' responses to these questions were used as a measure of their confidence in implementing each pillar of the lesson. The average rating of the five questions was used as a measurement of the teachers' overall confidence for each lesson.

b) Implementation

The teachers were also asked to describe the strategies they employed, and questions they asked, during each pillar of the lesson. Five questions were considered in this analysis, namely:

Q6	*How did you set up the concrete preparation at the beginning of the lesson? What questions did you ask?*
Q7	*What incident/discussion arose in the lesson that caused the cognitive conflict for the students? Was this brought about by you or by the students?*
Q10	*What questions did you ask to guide the students through the 'cognitive conflict"?*
Q15	*What strategies did you use to get the students to think about their thinking during the Metacognition part of the lesson?*
Q16	*In what way were you able to bridge the CASE lesson to any other topic they have covered/will cover?*

The teachers' written responses were catagorised on a scale of 0-3, with 0 being unsuccessful, and 3 being very successful. The rating assigned to the teachers' responses was used to gauge how successful the teachers' implementation of each pillar of the lesson was. Again, the average was calculated and used as an overall measurement of the teachers' success in implementing each lesson. This categorisation of responses is discussed in the next section.

4.1.1 Scaling teachers' responses to the Lesson Reflections

The scaling of teachers' responses was often specific to each lesson. The researcher completed an 'ideal' Lesson Reflection for each lesson, which was used as a benchmark. In general, a response assigned a 0 indicated that the teacher's attempt to implement the pillar was entirely unsuccessful, or the item was left blank. An answer assigned a 1 signified that the teachers' efforts were largely unsuccessful although some appropriate attempt at implementing the pillar was made. A response assigned a 2 indicates that the teachers' attempt was somewhat successful, although there was some margin for improvement. A 3 was assigned if the teacher's implementation of the pillar was successful. Examples of how responses were typically scaled for each pillar of the CASE lesson are discussed below.

- **Concrete preparation**

Question 6 on the Lesson Reflection asked the teachers to describe how they implemented the pillar of concrete preparation. In this phase, the teacher should introduce the task and discuss any new vocabulary or equipment. Ideally, the teacher will move beyond focusing on the practical side of the lessons, and provoke students to recall any previous thinking they have engaged in that will help with this task. When scaling the teachers' responses, a zero was assigned if the item was left blank. Teachers were assigned a 1 if they focused exclusively on the equipment involved, rather than on student thinking. A response assigned a 2 typically moved beyond focusing solely on the resources, but still did not refer to the students' thinking. A score of 3 was assigned if the teacher questioned the students on previous lessons, or types of thinking that they have engaged in, that may help with the task. New vocabulary and equipment should be discussed and students should be encouraged to plan. An overview of the scaling applied to the teachers' implementation of the pillar of concrete preparation is presented in Table 4.1, with examples of teacher responses.

Table 4.1: Scaling of teachers' responses to Question 6 on the Lesson Reflection: Implementation of Concrete Preparation

Scale	Description	Quote from Lesson Reflection
0	Left blank	
1	Heavy focus on resources	*Given pictures of bones and divide class into groups* (T24.L4)
2	Explaining task to students	*Children are grouped for the term according to mixed abilities (and behaviour compatibility criteria) roles where designated by me: scribe/leader/reporter and I explained the task. (T18.L4)*
3	Questions on previous thinking	"*Discussed what variables are and the difference between input and output variables. Asked the children to explain the thinking they did in the previous lessons. Explained the task. Asked for predictions/possible relationships*" (T27.L3)

- **Cognitive conflict/Social construction**

The teachers' management of the pillars of cognitive conflict and social construction were analysed concurrently. Cognitive conflict gives rise to social construction and vice versa. The teacher guides the students through the challenge by facilitating the discussion, therefore it is difficult to analyse the two aspects separately. Question 7 on the Lesson Reflection asked the teachers to describe the types of questions they asked to guide their students through the cognitive conflict aspect of the lesson. Questions posed by the teacher in this phase of the lesson should challenge the students to extend their thinking beyond their current capabilities. Ideally, questions should focus on the student's thinking or the schema involved, rather than on the scientific content. A zero was assigned if the teacher did not ask any questions to challenge the students' thinking, or if this item was left blank. A response was assigned a 1 if the teacher asked closed questions that focused solely on the results the students obtained. These questions were not followed up with any thought provoking questions. Responses assigned a 2 were more open-ended questions than the previous, and required the students to provide valid explanations for their answers. A 3 was assigned if the questions asked by the teacher were completely open-ended and attempted to extend the students' cognitive abilities. An overview of the scaling applied to the teachers' implementation of the pillars of cognitive conflict and social construction is presented in Table 4.2, with examples of teacher responses.

Table 4.2: Scaling of teachers' responses to Question 10 on the Lesson Reflection: Implementation of the Cognitive Conflict/Social Construction

Scale	Description	Quote from Lesson Reflection
0	Completely unsuccessful	
1	Closed Questions	*Which animal eats ……? Does it eat……?(T1.L3)*
2	Questions asking students to explain their answers	*What will happen if you add water?* *Can you get it back? How? (T19.L13)* *What's the function of the vertebrae, scapula?* *Why did you put all the bones into this group?* *What are the similarities and differences between bones? (T21.L4)*
3	Completely open questions to challenge thinking	*Why are you doing that?* *What do you think you need to do with the rest of the pictures?* *Which picture does the guitar go with? (T3.L4)*

- **Metacognition**

In this phase, the teachers should encourage their students to become conscious of the thinking they engaged in during the lesson so that it can be generalised and employed in other, unrelated situations. Eliciting metacognitive thinking includes asking questions that encourage students to:

- *Describe what kind of thinking they did;*
- *Describe how they did their thinking, and*
- *Evaluate their thinking.*

(Fisher, 1998 [adapted from Schwartz & Parks, 1994])

In this phase of the lesson, the teachers should ask questions that will encourage the students to articulate the *thinking* that they did, rather than *what* they did or the conclusions they reached. When scaling the teachers' responses to the Lesson Reflections, a response was assigned a 0 if the teacher failed to ask any questions that would provoke metacognitive thought, or if the item was left blank. Responses assigned a zero were often questions to challenge the students' thinking during the lesson and, while this is good practice during the cognitive conflict/social construction phase of the lesson, they do not encourage the students to reflect on, or evaluate their thinking. A response was assigned a 1 if the teacher asked closed-questions encouraging students to reflect on their results. These questions tended to focus on the conclusions the students reached, rather than on the thinking they engaged in during the lesson. A response which was assigned a 2 moved beyond the conclusions reached by the students, and had an increased focus on their thinking. However, these sorts of questions did not explicitly ask students to articulate the thinking they engaged in while they solved the problem. Responses assigned a 3 asked students to evaluate their thinking during the lesson, describe any new thinking that they have learned and how they would tackle the problem if they were to do it again. An overview of the scaling applied to the teachers' implementation of the metacognition phase of the lesson is presented in Table 4.3.

Table 4.3: Scaling of teachers' responses to Question 15 on the Lesson Reflection: Implementation of Metacognition

Scale	Description	Quote from Lesson Reflection
0	Unsuccessful	*Probing questions and statements e.g. Where would you find this? (T24. L3)* *I put the sticks out on the table without an even starting point and asked the children was this a good idea? (T11.L4)*
1	Questions asking students to explain their answer/what they have learned	*I used lots of probing questions to get them to think about what they have learned (why certain animals cannot live in certain habitats and what they need to survive – water/grass etc) (T1.L1)*
2	Increased focus on thinking	*Which items were solids? Which were liquids? How did you figure it out? (T19.L12)*
3	Questions which encouraged students to verbalize and evaluate their thought process	*What have you been thinking about? How could you have thought about that differently? What have you learned? How did you learn that? (T17. L4)*

- **Bridging**

In the bridging phase, teachers should attempt to generalize the thinking performed within a CASE lesson to other areas of student learning. When scaling the responses to the Lesson Reflections, a score of zero was assigned if this item was left blank. A response was assigned a score of 1 if the teacher bridged the science content covered in the lesson to other areas of the curriculum. A '3' was assigned when the teacher applied the schema developed within the CASE lesson to other contexts. Example responses to for this item are shown in Table 4.4. Again, the score assigned to a response was specific to each lesson. For example, the main aim of some introductory lessons was to encourage the students to listen to each other/ learn to work in a group. In this instance, bridging listening/group-work skills was assigned a '3' as this was the main focus of the lesson.

Table 4.4: Example scaling of teachers' responses to Question 16 on the Lesson Reflection: Implementation of the pillar of Bridging

Scale	Description	Quote from Lesson Reflection
0	Not done	
1	Bridging content covered in lesson	"*The children completed research on endangered animals and presented projects to the class*" (T21.L8) "*Sound – High notes/Low notes*" (T27.L4)
3	Bridging Schema	*"Using classification in art to classify paintings in different ways" (T18.L6)*

An overview of the scaling applied to the teachers' Lesson Reflection responses, in relation to their implementation of each pillar, is presented in Figure 4.5. This numerical data, along with the teachers' self-rating of the their implementation of each pillar, was used to determine if there was any change in the teachers' confidence and implementation of the CASE lessons during the year. The teachers' confidence is measured on a scale of 1 to 5, while the teachers' responses to the Lesson Reflections in relation to their implementation was scaled from 0 to 3. This is discussed in detail in Chapter 6.

Table 4.5: Overview of the scaling applied to the teachers' responses to the Lesson Reflections in relation to their implementation

	1	2	3
Concrete Preparation	Focused on resources	Introduced task but does not encourage students to think about previous thinking	Encouraged students to think about any previous thinking that they have engaged in that may help/encourage planning
Cognitive Conflict	Closed questions that focused solely on content. "What answer did you get?"	Questions which encouraged students to give an explanation for their answer	Completely open questions that challenged students.
Metacognition	Questions which focused solely on the results students obtained	Questions that encouraged students to reflect on what they did ask	Questions which asked students to describe and evaluate their thinking
Bridging	Bridging content covered in the lesson		Bridging thinking/schema covered in the lesson

4.2 Researcher Observations

As previously discussed in Chapter 3, researcher observations were used as a data collection method in the whole-school implementation phase of this study. The teachers of 2nd to 6th class were observed between 3 and 7 times throughout the programme. The researcher used a semi-structured instrument to evaluate the teachers' success in implementing the lesson. The researcher rated the teachers' implementation of a number of aspects of the lesson on a scale of 1-5, with 1 being unsuccessful, and 5 being very successful. The aspects of the lesson rated by the researcher were:

i. *Overall, how successful was the lesson?*

ii. *How successful was the teacher in their implementation of the pillar of concrete preparation?*

iii. *How successful was the teacher in guiding their students through the cognitive conflict/social discussion?*

iv. *How successful was the teacher at not telling the students the answer?*

v. *How successful was the teacher at eliciting metacognitive thinking from their students?*

The aspects of the lesson rated by the researcher, correspond with the teachers' self-rating as described in Section 4.1 in relation to their confidence. The researchers' observation rating could then be used as a measure of the overall success of the lesson, and compared with the teachers' self-rating generated from their responses to the Lesson Reflections. This is discussed in more detail in Chapter 6.

4.3 Multi-dimensional Scaling Analysis

4.3.1 Description of analysis technique

The teachers' data from the Lesson Reflections was analysed using multidimensional scaling (MDS). MDS is an analysis technique that graphically displays dissimilarities (or similarities) among objects (Jaworska & Chupetlouska-Anastasova, 2009; Young & Hamer, 1987). The overall aim of MDS is to create a configuration of points in which the distance between the points correspond as close as possible to the proximities between the objects (Kruskal, 1964). Objects that are considered similar to each other are represented by points that are close together on the configuration. The dissimilarities, (δ), between objects can be collected directly, or computed indirectly. They are then optically scaled to give a set of values known as disparities (d^*) (Jaworska & Chupetlouska-Anastasova, 2009; Young & Hamer, 1987). These disparities are input into an MDS model and undergo a specific type of analysis to generate a set of distances, d, that can be plot on n number of dimensions.

4.3.2. Applications of MDS analysis

MDS is a flexible analysis technique, which can be applied to many contexts. It is extensively used in the psychometric and marketing domains as it generates a visual representation of multivariate data. MDS is widely used to study peoples perceptions and attitudes including perceptions of social structures (Nzelek *et al*., 2001), academic dishonesty (Schrnelkin *et al*., 2010), emotions (Izmailov & Sokolov, 1991) and attitudes towards crime (Forgas, J. P., 1979). It has also been used in counselling psychology (Armstrong *et al*., 2008) and to assess students' attitudes towards science careers (Masnick *et al*., 2010). MDS is also commonly used in the area of market research to identify key dimensions underlying customer evaluations of products, services or companies (Cha, *et* al., 2009; Desourbo *et al*., 2002; Dotson *et al*., 2004). Subjects are asked to rank objects by their similarity (or dissimilarity) and the results are represented visually.

4.3.3 ALSCAL programme

There are several programmes that run MDS analysis depending on the type and nature of the data being analysed. In this study, the ALSCAL programme was used on SPSS v19. Within the ALSCAL programme there are numerous MDS models, which can be applied in several ways. Careful consideration must be given to the nature of the input data before choosing a model and a form of analysis to employ (Young & Hamer, 1987), as discussed below.

a) Shape of the data

Input matrices can be either square or rectangular in shape (Arce & Garling, 1989; Young & Hamer, 1987). In a square matrix, the columns and rows represent the same objects. Square matrices can be further defined as symmetric or asymmetric. In a symmetric matrix, the dissimilarity, δ, between A and B is equal to the dissimilarity between B and A ($\delta A = \delta B$). In this matrix, only the lower triangle is used in the MDS analysis, as the matrix is symmetrical. If the matrix is asymmetrical, the dissimilarity from A to B is not equal to the dissimilarity from B to A ($\delta A \neq \delta B$). In this instance, the upper and lower triangles of the matrix are not equal and are both included in the analysis. A matrix in which the columns and the rows represent different objects is said to be rectangular.

b) Number of input matrices

The input data can consist of single or multiple matrices, also known as '*ways*' (Arce & Garling, 1989; Young & Hamer, 1987). If the input data consists of one matrix it is referred to as 'two-way'. Data analysis dealing with more than one matrix is referred to as 'three-way'. The matrices are analysed simultaneously and one plot is generated. Data with multiple matrices is often used when several different participants are analysed concurrently or if the same participant is studied more than once (Jaworska & Chupetlouska-Anastasova, 2009).

c) Number of modes

The term mode refers to the number of variables being analysed (Arce & Garling, 1989; Young & Hamer, 1987). The input matrix can have one, two or three modes. In one mode data only one variable is analysed (and the matrix shape is therefore square).

d) Level of measurement

The data can be classified as metric or non-metric. Metric data is either interval or ratio, while non-metric data is ordinal. In non-metric MDS only the rank order of the data, and not the numerical values are preserved (Young & Hamer, 1987).

e) Measurement process

The data in the input matrix can be treated as discrete or continuous. Before undergoing MDS analysis, the data is optimally scaled to give a set of values known as disparities (d*) so that:

$$d^*_{ijk} = \perp[\delta_{ijk}]$$

where $\perp$ is a specific transformation dependent on the measurement level and process of the data. The data is assumed to be categorical and if treated as discrete, dissimilarities which are in the same category are represented by the same value after transformation (Young & Hamer, 1987). Ordinal data treated as discrete (do) is transformed under the following equation:

$$\perp^{do}: (\delta_{ijk} \approx \delta_{mno}) \rightarrow (d^*_{ijk} = d^*_{mno}) \quad \text{and if}$$

$$\perp^{do}: (\delta_{ijk} < \delta_{mno}) \rightarrow (d^*_{ijk} \leq d^*_{mno})$$

where δ_{ijk} is the dissimilarity between *i* and *j* on matrix *k*. If the ordinal data is considered continuous (co), each dissimilarity within a category is represented by a real number within an interim of real numbers so that:

$$\perp^{co}: (\delta_{ijk} \approx \delta_{mno}) \rightarrow (d^-_{ijk} = d^-_{mno}) \leq (d^*_{ijk}, d^*_{mno}) \leq (d^+_{ijk} = d^+_{mno})$$

where d^-_{ijk} and d^+_{ijk} are the lower and upper limits of the interval of possible real numbers of d^*_{ijk}.

f) Conditionality

Conditionality refers to the relationships that may exist among observations (Young & Hamer, 1987). There are several types of conditionality

- Matrix conditional
- Row conditional
- Column conditional
- Unconditional

The conditionality limits the comparisons of dissimilarities to within the chosen condition i.e. if there is more than one input matrix, and the data is matrix conditional, then the dissimilarities are limited to being compared within each matrix. If the data is row conditional then the data in row 1 of each matrix is compared with each other and the same from row 2 etc.

The default for the ALSCAL programme is single, symmetric matrix of discrete data (that is matrix conditional).

4.3.4. MDS Model and analysis

Young and Hamer (1987) distinguishes between an MDS model and MDS analysis. An MDS model is an algebraic equation that generates a simple geometric representation, while MDS analysis refers to how the chosen model is applied. MDS models can be weighted or unweighted. Unweighted models are the most basic, while weighted models take individuals perception and cognitive processes into account (Jaworska & Chupetlouska-Anastasova, 2009) i.e. each subject may weigh aspects differently. ASCAL uses three unweighted MDS models, all of which are variations of the Minkowski model:

$$d^p_{ij} = \sum_{a}^{r} |x_{ia} - x_{ja}|^p \qquad (p \geq 1) \text{ and } x_i \neq x_j$$

where d_{ij} is the distance between *i* and *j*, x_{ia} is the co-ordinates of point *i* on plane *a*, p is the Minkowski exponent and *r* is the number of dimensions. The number of possible dimensions on the ALSCAL programme ranges from 1 to 6, however 2 or 3 are most often used (Young & Hamer, 1987).

Varying *p*, the Minkowski exponent, changes the model used. The Minkowski exponent cannot be less than 1. When *p* equals 2, it is referred to as the Euclidean distance model, which is the default model used by the ALSCAL programme. This model is often used when the researcher knows very little about the process that generated the dissimilarities (Jaworska & Chupetlouska-Anastasova, 2009). The Euclidean distance model in 2 dimensions (r=2) is represented by:

$$d^2_{ij} = \sum_{a}^{2} |x_{ia} - x_{ja}|^2$$

In this instance, the distance, d_{ij} , is defined as the square root of the sum of squared differences between co-ordinates.

Types of MDS Analysis

Schiffman, *et al.* (1981) identify four types of analysis based on the unweighted Minkowski model. The four types are classified according to the nature of the input data. They are:

- Classical multidimensional scaling (CMDS)
- Replicated multidimensional scaling (RMDS)
- Classical multidimensional unfolding (CMDU)
- Replicated multidimensional unfolding (RMDU)

Classical MDS (CMDS) is the most basic form of MDS and manages single matrices of square, symmetric data that are matric conditional. Replicated MDS (RMDS) manages multiple matrices of square data simultaneously. RMDS is most often matrix conditional and can be used to analyse multiple subjects concurrently generating a single plot. An advantage of using RDMS instead of carrying out multiple CMDS analysis is that often times an interaction might become apparent that you would not be observed from multiple CMDS plots (Jaworska & Chupetlouska-Anastasova, 2009). CMDU manages one matrix of rectangular data that is row conditional. Stimuli and subjects are represented by two sets of points that represent the dissimilarities as much as possible. (Young & Hamer, 1987). Replicated MDU (RMDU) only differs from CMDU in that it analyses multiple matrices of rectangular data simultaneously, as shown in Table 4.6.

Table 4.6: Types of MDS analysis available within the ALSCAL programme on SPSS V.19

Analysis	Shape	No. of matrices	Condition
CMDS	Square	1	Matrix
RMDS	Square	2	Matrix
CMDU	Rectangle	1	Row
RMDU	Rectangle	2	Row

There are additional forms of MDS analysis that read asymmetrical and weighted data, such as weighted multidimensional scaling (WMDS) also referred to as individual differences MDS (INDSCAL), ALSCAL and AINDS (Arce & Garling, 1989; Young & Hamer, 1987).

4.3.5. Application of MDS in this study

Classical MDS analysis was applied to the data generated from the teachers' responses to the Lesson Reflections, and used to analyse any change in teachers' i) confidence and ii) implementation of the lessons. The Euclidean distance model was used and the configuration plot in 2 dimensions. The dissimilarities were computed as Euclidean distances indirectly from a rectangular matrix, in which the columns represented teachers, and rows represented responses to items in the Lesson Reflections. The resulting input matrix of dissimilarities was symmetrical so that both the rows and the columns represent teachers. In CMDS the data undergoes a number of steps:

- The scaled disparities are represented as randomly assigned points on a plane.
- The points are computed to fit the appropriate model so that the inter-point distances represent the data to a reasonable extent. In non-metric CMDS, only the rank order of the data, and not the numerical values are preserved
- Young's stress is measured to determine the variance between the configuration distances and the dissimilarities i.e. a measure of how well the configuration fits the experimental data. The stress is measured between 0 and 1 with a lower stress value indicating a better fit.
- The configuration undergoes an iterative process that re-plots the co-ordinates to improve the stress value. This is repeated until the improvement is less than 0.001 or after 30 iterations, which are the default settings for the ALSCAL programme.

In this study, MDS was useful to display the similarities of teachers' responses to the lesson reflections and also to monitor their change in response over time. The results of this analysis are discussed in detail in Chapter 6.

Chapter 5

Overview of Participating Teachers

Introduction

This chapter provides a brief overview of the school, the teachers' background and practices in relation to science prior to engaging with the CASE methodology. The teachers completed a questionnaire (Q1) which sought to establish:

- the participants background and current practice in relation to science education;
- their confidence in teaching science, and
- the importance and emphasis placed on scientific skill development within their teaching of science.

In total, 25 teachers responded to the questionnaire; however, one teacher, T1, returned a questionnaire with two pages missing, and is only included in sections of the analysis.

5.1.The Case Study School and Teacher Information

The study school is a large, suburban, mixed primary school with approximately 900 students. There are four classes at each level, excluding the 6th class group that has three. There are a total of 31 class teachers, seven learning support teachers and two language support teachers in the school. The teachers had broad range of teaching experience, from one to 34 years, with 11 of the 25 respondents having 6 years or less teaching experience. The most common qualification held by the teachers was a Bachelors of Education, or a Bachelors of Arts combined with a postgraduate diploma in education. Seven of the respondents also had a Masters in Education, and one teacher (T25) had a Bachelors of Science with a postgraduate diploma in education.

The school has a whole school science plan with one one-hour lesson taught every 2 weeks. The science plan follows the spiral approach laid out in the primary science curriculum so that each topic is encountered once every 2 years. One teacher (T25) has been appointed science coordinator and overseas science planning and equipment in the school. The teachers were previously involved in a whole-school professional development programme to improve the teaching of physical education in their school (Coulter, 2012).

The majority of the teachers (20) studied science education during their initial teacher education; however, eight teachers felt that this did not sufficiently prepare them to teach primary school science. A further five teachers did not complete any science education modules as part of their teacher training. Two of these teachers have over 15 years teaching experience, and completed their teacher education prior to the introduction of the revised primary science curriculum. All of the respondents studied science at second-level, excluding T1 (Junior Infants) and T21 (4^{th} Class), who did not. Both of the teachers studied science during the teacher education, although T21 did not feel that this prepared her to teach primary school science. Of the remaining twenty-three teachers, twenty-one studied a science subject to Leaving Certificate level. Biology was the most common subject studied (20 teachers) while one teacher (T25) studied physics and another (T27) studied a combined chemistry/physics course. These figures agree with the concerns highlighted by the DES (2012), that Irish primary teachers have little or no experience with physical science subjects. In relation to professional development, seven of the teachers participated in the in-service provided by the Primary School Support Programme (PSSP) after the introduction of the revised science curriculum in 2003 (T2, T6, T11, T17, T18, T24, T27). T11 and T27 participated in additional science professional development courses outside of school hours.

5.2 Teachers' classroom practices in relation to science, prior to the study

In the school year prior to the implementation of the CASE programme, science was taught on average once per week, as recommended by the primary school curriculum. At the 3rd to 6th class level, science classes generally lasted between 45 - 60 minutes. The teachers of Junior Infants to 2nd class spent less time teaching science with an average class lasting between 35 – 45 minutes. All teachers taught the stands '*Living things*' and '*Environmental awareness and care*' the year previous to the implementation of the CASE methodology. T29 did not teach the strand '*Materials and change*' and T19 did not teach the strand '*Energy and forces*'. In general, the teachers considered all of the strands of the curriculum important, with the strands '*Living Things*' and '*Environmental Awareness and Care*' considered most important. T6 (Senior Infants) did not consider the strands '*Energy and Forces*' or '*Material and Change*' important.

The teachers were asked which aspects of science hinder them from teaching the strands of the curriculum. The main factors, which inhibit the teachers teaching science, were:

- Class size
- Lack of equipment
- Lack of confidence
- Too much organisation

These obstacles were primarily concerning the strand '*Energy and Forces*'.

In relation to teaching methods, the most frequently employed teaching methodology was direct teaching, as shown in Table 5.1. Four of the teachers (T3, T5, T10 and T18) rarely used guided discovery.

Table 5.1: Teaching strategies employed by teachers prior to teaching the CASE methodology

	Very Frequently	Frequently	Rarely	Never
Guided Discovery	6	14	4	0
Group Teaching	10	6	6	1
Direct Teaching	13	8	3	0

5.3 Confidence in Curriculum Content

The teachers were generally confident teaching the content of all of the strands of the curriculum. The teachers were slightly less confident teaching the strand '*Energy and Forces'* with three teachers (T2, T14, T19) considering themselves not confident. There was no significant difference in the confidence levels between the teachers of Junior Infants to 2nd class and the teachers of 3rd to 6th class, as shown in Table 5.2.

Table 5.2: Teachers' confidence in teaching the strands of the curriculum

	Very Confident		Confident		Fairly Confident		Not Confident	
	Jnr - 2nd	3rd-6th	Jnr - 2nd	3rd-6th	Jnr - 2nd	3rd-6th	Jnr - 2nd	3rd-6th
Living Things	7	7	3	5	1	1	0	0
Energy and Forces	3	2	4	7	2	3	2	1
Materials	4	4	4	7	3	2	0	0
Environmental awareness and Care	7	8	4	5	0	0	0	0
Total	21	21	15	24	6	6	2	1

Although the teachers appear to be quite confident teaching the content of the curriculum, when asked to describe their main weaknesses as a science teacher, a lack of content knowledge and a lack of confidence were two of the most cited weaknesses as shown in Table 5.3. A personal interest in science was the most mentioned strength in teaching science.

Table 5.3: Teachers' most cited strengths/weaknesses in teaching science in Questionnaire 1

Strength	No. of teachers	Weakness	No. of teachers
Personal Interest in science	13	Lack of content knowledge	10
Organised	6	Lack of confidence	6
Encourage students to experiment	4	Don't spend enough time teaching science	6
Allow their students to work in groups	4	Unorganised	5

5.4 Scientific Skill Development

In general, the teachers considered the development of the scientific skills, as described in the curriculum documentation, as either 'very important' or 'important'. Questioning was considered the most important skill, while designing and making was considered slightly less important. In their responses to Q1, the teachers stated that they placed 'a lot' or 'some' emphasis on the development of all of the scientific skills in their teaching, excluding T27 who responded that she generally placed 'little' emphasis on development of students' scientific skills. Again, the teachers placed the most emphasis upon developing the skill of questioning, and slightly less emphasis upon designing and making. In general, the teachers were confident in their ability to develop their students' scientific skills, however six teachers (T5, T11, T14, T21, T26, T27) considered themselves not very confident. The teachers were also confident in their ability to:

- Plan lessons
- Use equipment
- Manage paired/group activities
- Manage whole-class activities
- Ensure the safety of all students

Summary

All of the teachers had previously studied science either in secondary school or during their teacher education programmes; however, only two teachers studied a physical science subject at Leaving Certificate level. The teachers' participation in professional development was quite low, with only two teachers participating in professional development beyond that supplied by the PSSP following the introduction of the revised curriculum. In general, the teachers considered themselves confident in relation to teaching science. The majority of teachers were confident in teaching all of the strands of the curriculum, however, a lack of content knowledge was the most frequently mentioned weakness as a science teacher. The teachers considered the development of all of the scientific skills as 'important' or 'very important' and generally place a 'lot' or 'some' emphasis on them in their teaching of science.

Chapter 6

Implementation of the CASE Lessons – Teacher Change

Introduction

This chapter discusses the teachers' implementation of the CASE lessons during the whole-school implementation phase of the study. A number of data sources are considered, as discussed in Chapter 3. These include the teachers' responses to the written lesson reflections, responses to Questionnaire 2, researcher observations and focus group discussions. This chapter is divided into seven sections. The first five sections (6.1 – 6.5) focus on the teachers of a specific class group/groups. Section 6.1 discusses the teachers of third and fourth class, and is discussed in the most detail. The teachers are analysed in relation to their overall change in confidence and implementation of the lessons. Each teacher's overall change is analysed first using multidimensional scaling. Teachers are classified according to their overall change, which is then explored in more detail. Subsequent sections (6.2 – 6.5) follow the same format but describe a different set of teachers. The teachers' ability to relate the schema to other areas of student learning (Bridging) is analysed in Section 6.6. Finally, the main findings of this analysis are discussed and summarized in Section 6.7.

6.1 Third and Fourth Class Teachers

6.1.1 Overview

The 3rd and 4th class group consists of eight teachers, four from each class level, as shown in Table 6.1. While T20 delivered the lessons and took part in focus group discussions, she did not complete any lesson reflections or questionnaires, and is therefore not considered in this analysis.

Table 6.1: Teachers of 3rd and 4th class

3rd Class	4th Class
T17	T21
T18	T22
T19	T23
T20	T24

For the purposes of this research, the 4th class students did not begin on the 4th class programme as discussed in Chapter 3. As previously mentioned, the CASE programmes are built on a spiral approach. In order to grasp the schema involved, the students must have some understanding of the activities that precede it. Therefore, it was not considered suitable to start the 4th class students half way through the *Let's Think through Science! 8&9* programme. The 4th class students began by completing the first eight lessons in the 3rd class programme, to gain a basic understanding of the CASE methodology and the schema involved, and then moved onto the 4th class programme in the second term. The lessons completed by the 3rd and 4th class group are presented in Tables 6.2 and 6.3 respectively. The lessons completed by each teacher and the lesson reflections received are also highlighted. The response rate to lesson reflections was generally good, although some teachers completed fewer lesson reflections than others.

Table 6.2: Lessons completed and lesson reflections received for the 3rd class teachers

		Third Class			
		T17	T18	T19	T20
L1	Climb that Mountain	✓	✓	✓	O
L2	Make that Box	✓	✓	✓	O
L3	Who am I?	✓	✓	✓	O
L4	All these Bones	✓	✓	✓	O
L5	What makes me Move?	✓	✓	✓	O
L6	Where do I Live?	✓	✓	✓	O
L7	How am I Adapted?	✓	✓	O	✗
L8	What am I?	✓	✓	O	O
L9	How hot are you?	✓	✓	✓	O
L10	Hotter or Colder?	✗	✓	✓	O
L11	I like my Tea Hot (a)	✓	✓	✓	✗
L12	I like my Tea Hot (b)	O	O	O	✗
L13	Where does it belong?	✓	✓	✓	O
L14	I can't find the Sugar	✓	✓	✓	✗
L15	Sorting out the mix-ups	✓	✗	✗	✗
Total Lesson Reflections Received		13	13	11	0

Table 6.3: Lessons completed and lesson reflections received for the 4th class teachers

		Fourth Class			
		T21	**T22**	**T23**	**T24**
L1	Climb that Mountain	✓	✓	✗	✓
L2	Make that Box	✓	✓	✗	✓
L3	Who am I?	✓	✓	✓	✓
L4	All these Bones	✓	✓	✓	✓
L5	What makes me Move?	✓	✓	✓	✓
L6	Where do I Live?	✓	✓	O	✓
L7	How am I Adapted?	✓	O	✗	O
L8	What am I?	✓	O	O	✓
L9	Where are the forces?	O	O	✗	✗
L10	Can you change the force?	✗	✗	✗	✗
L11	Bungee	✓	✓	✓	✓
L12	Falling	✓	✓	✓	✗
L13	Parachutes	✓	✓	✓	✓
L14	My bulb won't work	✓	✗	✓	✗
L15	Do I work? a)	✓	✗	✗	✗
Total Lesson Reflections Received		13	9	7	9

✓	Lesson completed and lesson reflection received.
O	Lesson completed. No lesson reflection received,
✗	Lesson not completed

A timeline highlighting the 3rd and 4th class group's implementation of the CASE lessons is presented in Figure 6.1. All teachers taught the same lessons (L1-8) until mid-way through the second term. The 3rd and 4th class teachers participated in Focus Groups (FG) 1 and 2 together, however, subsequent focus groups were held separately. After lesson 8, the 3rd class teachers continued with the third class programme, while the 4th class teachers progressed to the fourth class programme. Therefore, in Figure 6.1, lessons numbered L1 - L8 are the same lessons for all teachers. However, later lessons implemented do not refer to the same lesson for the 3rd and 4th class teachers. For example, T17.L11 refers to the T17's implementation of lesson 11 in the 3rd class programme (*I like my tea hot (a)*), while T21.L11 refers to T21's implementation of lesson 11 in the 4th class programme (*Bungee*).

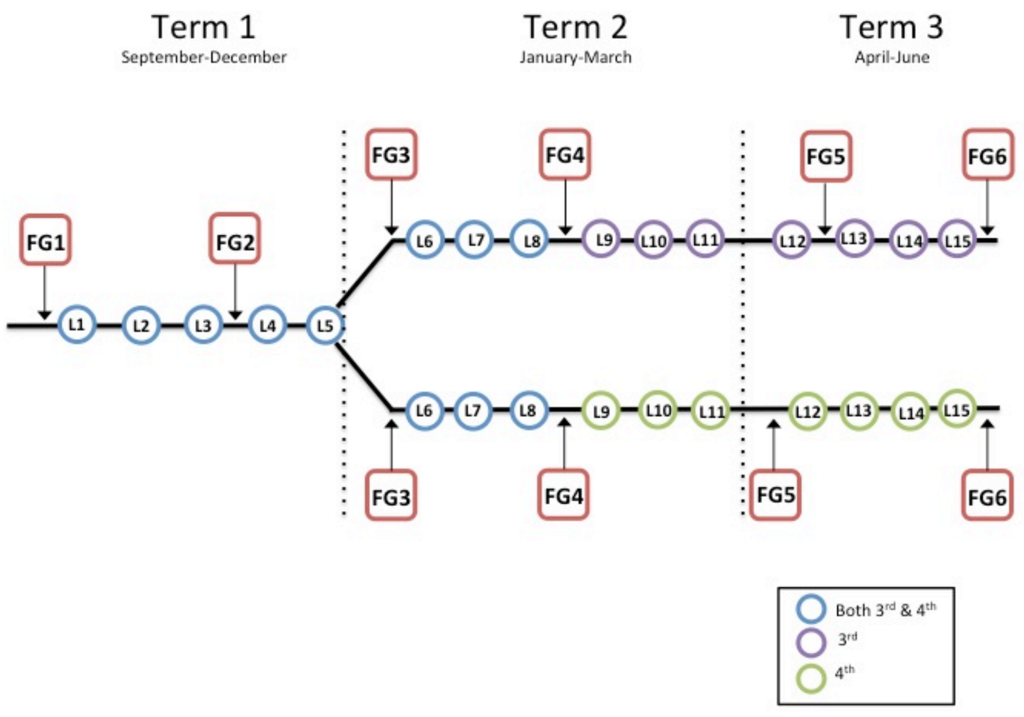

Figure 6.1: Timeline for the 3rd and 4th class groups' implementation of the CASE lessons

6.1.2 Implementation of the CASE lessons

The teachers' lesson reflections were analysed as described in Chapter 4 to obtain a measure of each teachers' confidence and implementation for each lesson. To analyse the teachers' progress during the programme, their implementation rating was plotted against their confidence rating for each lesson, as shown in Figures 6.2 and 6.3. In relation to the teachers' implementation of the lessons, an average rating of 2 or above was considered successful with reference to how the teachers' responses to the lesson reflections were scaled in Chapter 4. A teacher whose confidence rating was 4 or above was considered confident in their implementation of the lesson. A rating of below 4 was not considered confident. Ideally, the teachers will be located in the top right quadrant on the graph, which signifies that they are both confident and successful in their implementation of the lesson.

Figures 6.2 and 6.3 highlight that each lesson was implemented with varying degrees of success by the seven teachers, as shown by the variation of points over the whole fifteen lessons. No single lesson, or group of lessons, proved to be more difficult to implement than others. Generally, the 3rd class teachers were more successful in their implementation than the 4th class teachers. A number of lessons implemented towards the end of the programme (L8, L9, L11, L13, L15), were implemented successfully by the 3rd class teachers, indicating that there was some overall improvement in their implementation as the programme progressed. The 4th class teachers' did not display any steady improvement in their implementation or confidence as the programme progressed. The lack of steady improvement for each lesson implied that progress was dependent on the individual teacher, and not on the lessons themselves. To analyse the change in teachers' implementation and confidence in more detail, the teachers' reflections were analysed using multidimensional scaling (MDS).

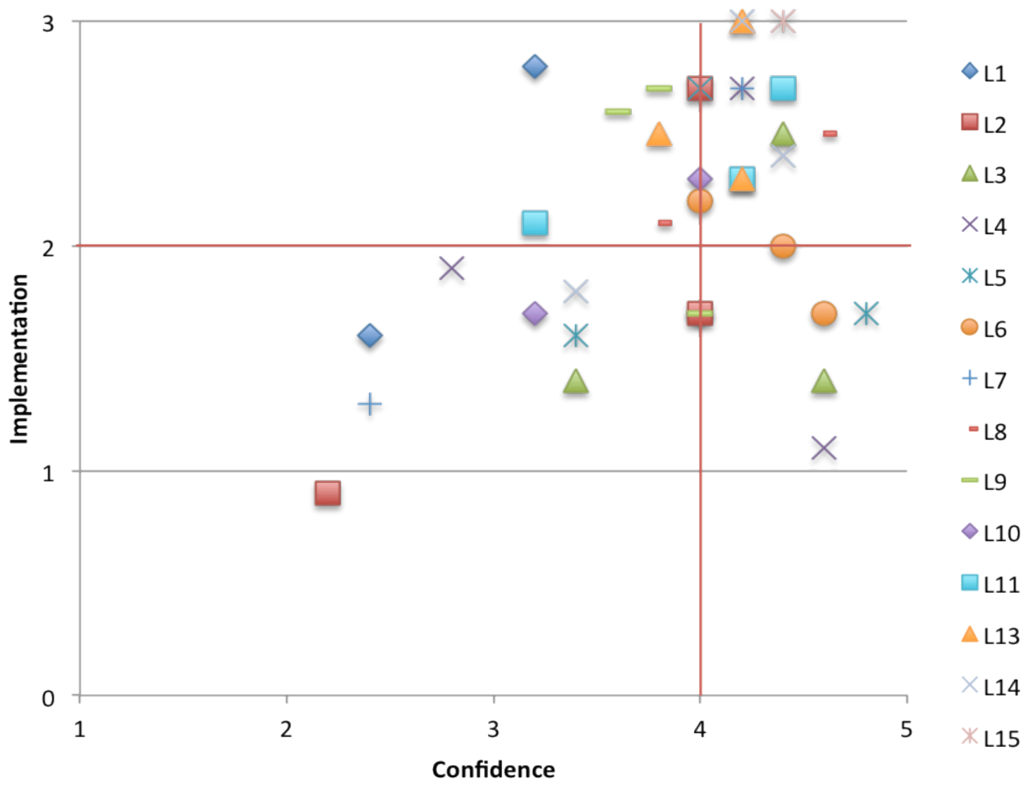

Figure 6.2: 3rd class teachers' confidence versus implementation for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.2

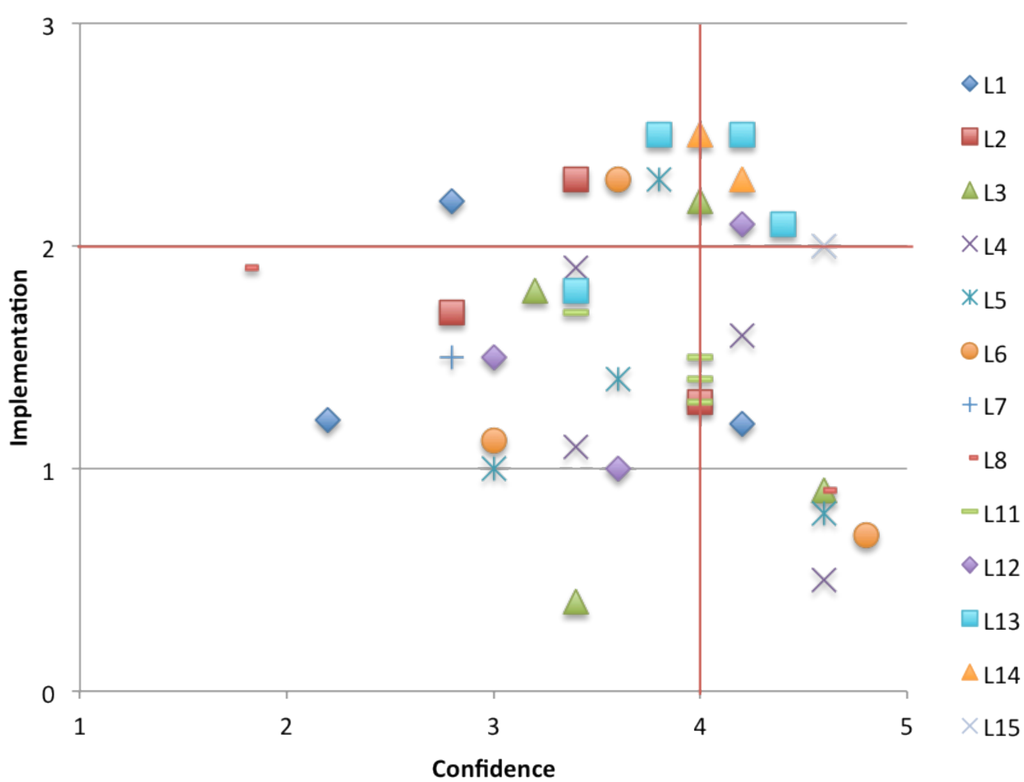

Figure 6.3: 4th class teachers' confidence versus implementation for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.3.

6.1.3 Multidimensional scaling analysis

The teachers' responses to the lesson relfections were analysed, as described in Chapter 4. Classical non-metric multidimensional scaling (CMDS) was applied to measure any change in their confidence and implementation of the lessons, from the beginning of term one, to the end of term three. Data for each teacher was analysed in relation to both elements seperately. The teachers' ratings for the first three CASE lessons implemented were used as a measurement of the teachers' implementation (and confidence) at the beginning of the programme, while the last three lessons were used as a measure at the end. These were selected to maximise the data set and to examine the overall change. The number of lesson reflections received from the teachers varied, therefore the first three and last three lessons analysed using MDS differed for each teacher. However, as the main focus of this research was to analyse individual teachers' progress, and not to compare how teachers implemented specific lessons, this was considered acceptable. L1 and L2 (*Climb that mountain* and *Make that box)* have been excluded from this analysis as they are introductory activities and, while they concentrate on such elements as group work and listening, they do not focus on any of the schema of concrete operations. As these activites differ from the other CASE lessons, they may give unreliable measures of teachers' implementation and confidence at the begining of the programme, and were not considered appropriate for this analysis.

Each teacher is represented by two points on the MDS configuration: one representing the teachers' implementation (or confidence) at the beginning of the programme (term one), and one representing the teacher at the end (term three). As the data is ordinal level, the distances have the same rank order as the input dissimilarites, and can therefore be interpreted as distance-like but not actual distances. Two points which are close together can be considered more similar than a third point which is situated far away i.e. two teachers that are close together can be considered similar.

The teachers' implementation (and confidence) was measured against an 'ideal' teacher. For the purposes of this research, the ideal teacher is a hypothetical teacher who is consistantly rated at the upper end of the scale for both their implementation and their confidence i.e. in terms of implementation, on a scale of 0-3, an ideal teacher is constantly rated as a 3 for all elements of all lessons. The ideal teacher is represented as a point in the configuration. MDS analysis considers all of the data in a given dataset. By including the 'ideal' teacher in the dataset the teachers' co-ordinates are plotted 'relative' to the ideal teacher. Therefore, a teacher who is considered similar to the ideal will be represented as a point close to the ideal on the configuration. The data is now discussed under two headings: (a) implementation and (b) confidence.

a) Implementation

Teachers' data for the first and last three lessons underwent MDS analysis and the configuration plot in two dimensions. The 3rd and 4th class teachers' proximity to the hypothetical ideal teacher in term 1 is presented in Figure 6.4. At the beginning of term one:

- T17 is closest to the hypothetical ideal teacher,
- T23 is also situated relatively close to the ideal
- The remaining teachers are all considerably distant from the ideal

This analysis highlights that T17's implementation of the lessons was the most successful of all seven teachers at the beginning of term 1. However, there is no indication of whether each teacher's implementation was considered successful or not. In order to consider this, the significance of the distance between each teacher and the hypothetical ideal teacher must be analysed, using the concept of a *Zone of Acceptable Proximity* (ZAP).

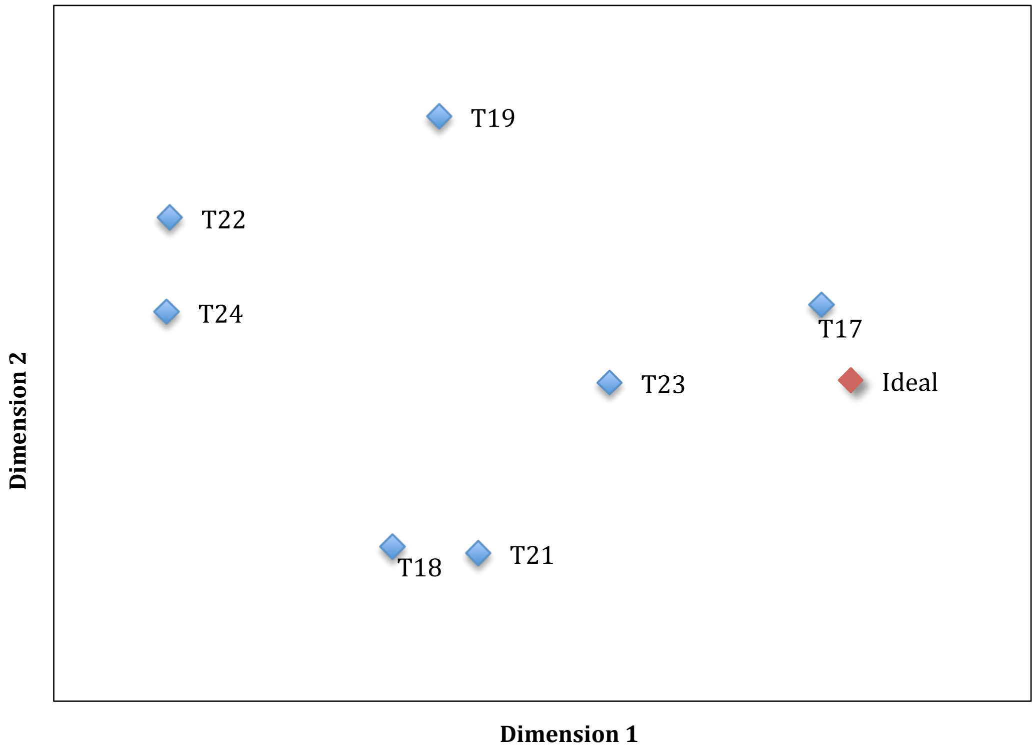

Figure 6.4: 3rd and 4th class teachers' proximity to the hypothetical ideal teacher in relation to their implementation at the beginning of term 1.

The Zone of Acceptable Proximity (ZAP)

In order to analyse whether the teachers' implementation of the lessons was successful using the configuration, a *Zone of Acceptable Proximity* (ZAP) was constructed surrounding the hypothetical ideal teacher, as shown in Figure 6.5. The ZAP describes a region on the configuration in which two points are considered 'similar'. Therefore, a teacher whose co-ordinates are situated within the ZAP of the ideal teacher in Figure 6.5 is considered similar to the hypothetical ideal i.e. the teacher is successful in their implementation of the lessons. As previously discussed, a rating of 2 or above is considered successful in relation to the implementation of the lessons. The ZAP was defined by reviewing the teachers' implementation rating, and identifying on the configuration those teachers whose rating was above/below 2. The boundary of the ZAP was then constructed to include those teachers whose implementation rating was above 2, and to exclude those whose rating was below 2. Therefore, in this instance, a teacher situated inside the ZAP is considered successful in their implementation. At the beginning of term one, T17 and T23 are situated within the ZAP, as shown in Figure 6.5.

However, T18, T19, T21, T22 and T24 are situated outside the ZAP indicating that their implementation of the lessons was largely unsuccessful.

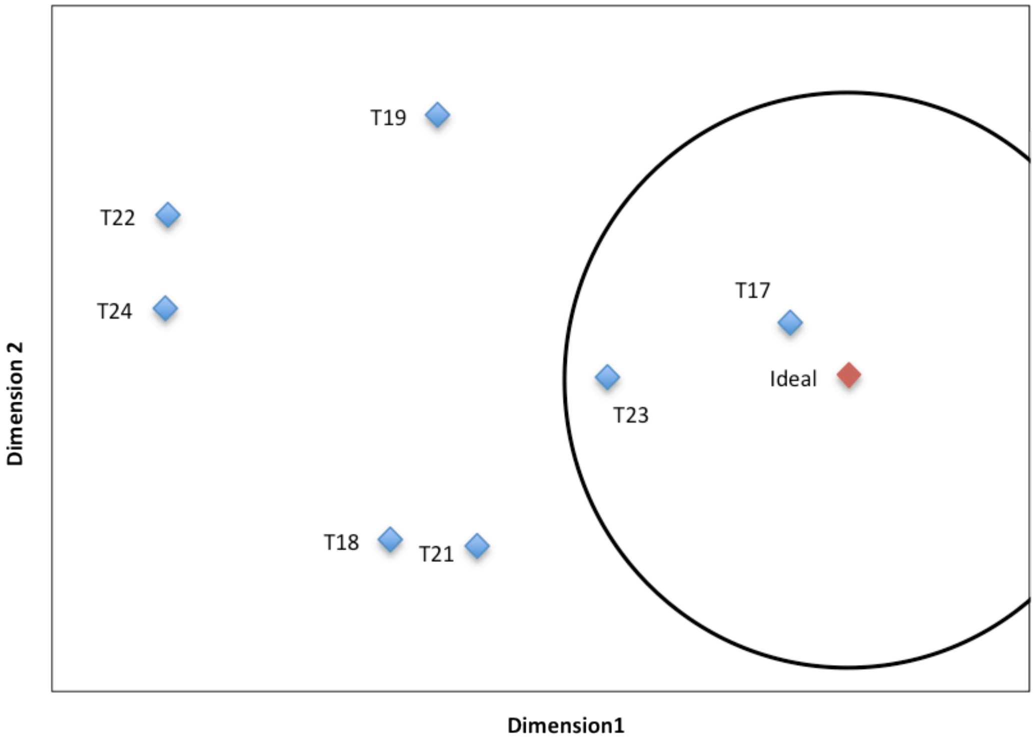

Figure 6.5: 3rd and 4th class teachers' implementation with regard to the ZAP at the beginning of term one. Only teachers inside the ZAP are considered successful in their implementation.

The change in teachers' implementation of the lessons from term one to term three can then be discussed with regard to their movement in or out of the ZAP, as shown in Figure 6.6. Each of the seven teachers is represented by two points on the configuration, one for the beginning (term one) and one for the end of the programme (term three). An 'x' beside the teacher code on the configuration indicates the teachers' proximity to the ideal teacher at the end of the programme. Figure 6.6 highlights that at the end of term three:

- T17 remains within the ZAP and is the closest point to the ideal.
- T23 has moved away from the ideal and out of the ZAP. T23x is situated in a region where the teacher is no longer considered similar to the ideal. This signifies that T23's implementation of the lessons was largely unsuccessful in term three.

- T18, T19 and T21 move towards the ideal teacher and into the ZAP indicating that their implementation is reasonably successful at the end of term three
- T22 and T24 move towards the ideal, however they remain outside the ZAP at the end of term three. This indicates that, while the teachers improved in relation to their implementation of the lessons, their efforts are largely unsuccessful at the end of term three.

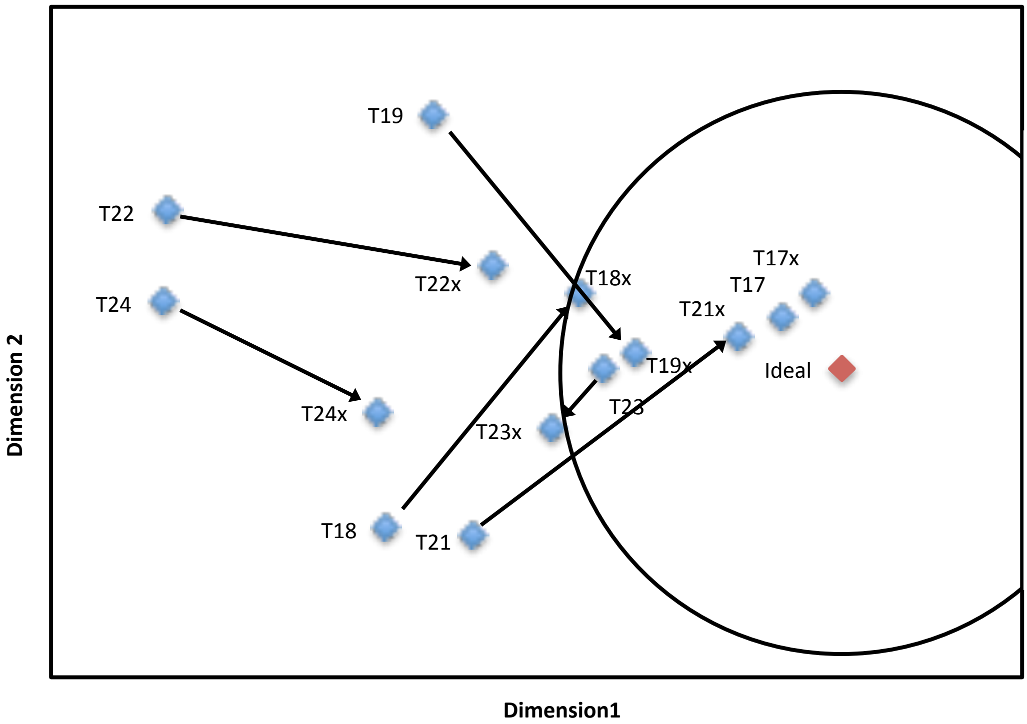

Figure 6.6: 3rd and 4th class teachers' change in implementation with regard to the ZAP from term one to term three (T=Term 1, Tx = Term 3)

The teachers were classified into four groups according to their movement in/out of the ZAP, in relation to their implementation. Table 6.4 highlights that, at the end of term three, four of the 3rd and 4th class teachers' were generally successful in their implementation of the CASE lessons. T22 and T24 improved in their implementation of the lessons; however, they remained outside the ZAP at the end of term three. T23 was situated within the ZAP in term one, however the teacher moved out of the ZAP in term three, indicating that her implementation of the lessons was no longer successful.

Table 6.4: Classification of the 3rd and 4th class teachers in relation to their implementation

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T17
2	Outside ZAP	Inside ZAP	T19, T21, T18
3	Outside ZAP	Outside ZAP	T22, T24
4	Inside ZAP	Outside ZAP	T23

b) Confidence

The teachers' change in confidence was also analysed using MDS. Again, the ZAP was outlined and used to evaluate the teachers' confidence at the beginning of term one, and at the end of term three. The ZAP was defined by analysing the teachers' average confidence for the first and last three lessons implemented. A rating of 4 or above was considered confident while anything below was considered lacking in confidence. The ZAP was constructed to include those teachers whose average confidence rating was above 4, and to exclude those whose average was below 4. Therefore, a teacher situated within the ZAP in this instance is considered confident, while a teacher situated outside the ZAP is not considered confident. Figure 6.7 highlights that, at the beginning of term one:

- T17, T19, T23 and T24 are situated within the ZAP, and are confident in their implementation of the lessons
- T19 and T24 are closest to the ideal
- T18, T21 and T22 are situated furthest from the hypothetical ideal, signifying that these three teachers are not confident in their ability to implement the lessons.

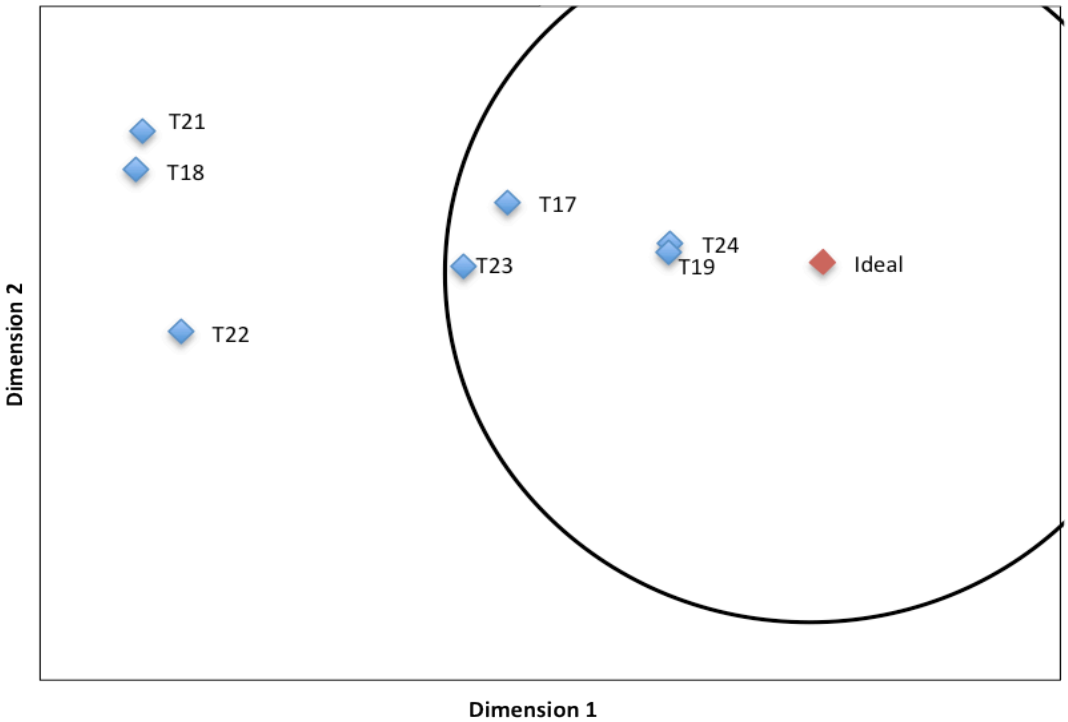

Figure 6.7: 3rd and 4th class teachers' confidence in their implementation with regard to the ZAP in at the beginning of term one.

Figure 6.8 highlights that, at the end of term three:

- T19 and T24, who were closest to the ideal in term one, moved slightly away. However, both teachers remained within the ZAP at the end of term three and are therefore considered confident.
- T17 has moved closer to the ideal and remains within the ZAP
- T23, who was situated in the ZAP in term one moves away from the ideal and out of the ZAP. This indicates that T23 is no longer confident in her ability to implement the lessons at the end of term three.
- T21, who was distant to ideal teacher at the beginning of term one, has moved into the ZAP and is confident in her ability to implement the CASE lessons at the end of term three
- T22 has also moved towards the ideal teacher however, at the end of term three, T22 remains just outside the ZAP indicating that she is not entirely confident.
- T18 made no significant movement towards the ideal. Figure 6.8 highlights that, while T18's confidence has changed relative to the ideal teacher from

term one to term three, the teacher remained outside the ZAP and is not considered confident in her implementation of the CASE lessons.

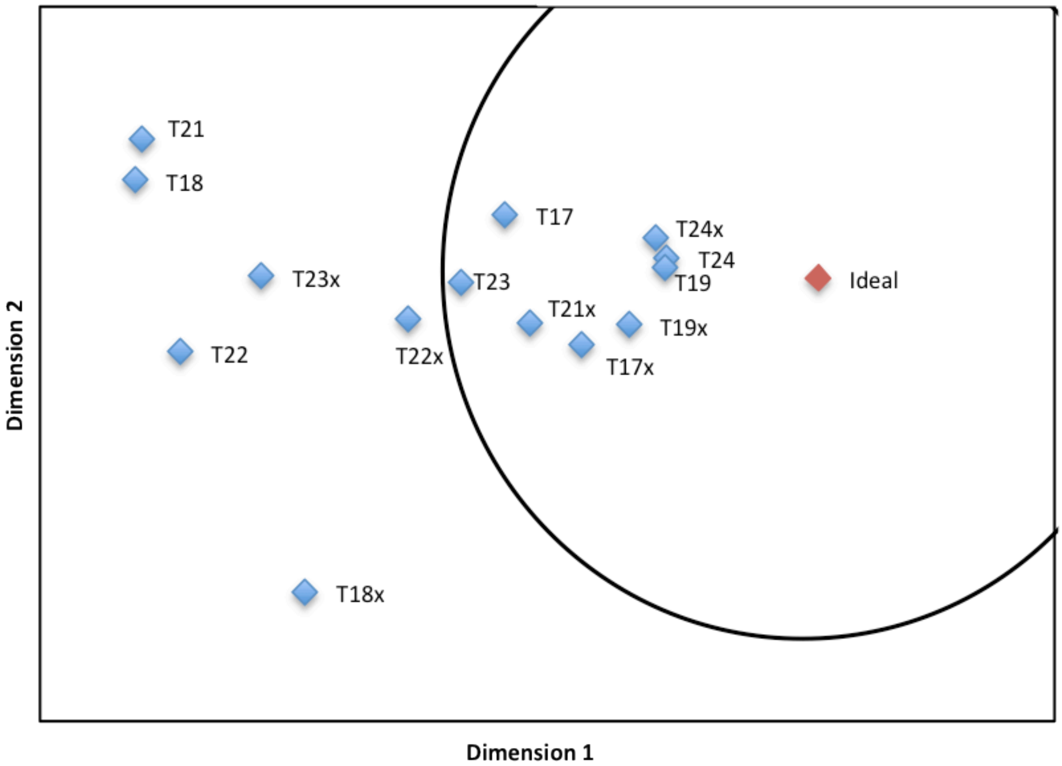

Figure 6.8: 3rd and 4th class teachers' change in confidence with regard to the ZAP from term one to term three

Again, the teachers were classified according to their movement relative to the ZAP, from the beginning of term one to the end of term three, as shown in Table 6.5. At the end of term three, four teachers (T17, T19, T24 and T21) were confident in their ability to implement the CASE lessons. T23, moved out of the ZAP from term one to term three, and is no longer considered confident. T18 and T22 remained outside the ZAP, indicating that they were not considered confident in their ability to implement the lessons throughout the programme.

Table 6.5: Classification of the 3rd and 4th class teachers in relation to their confidence

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T17, T19, T24
2	Outside ZAP	Inside ZAP	T21
3	Outside ZAP	Outside ZAP	T18, T22
4	Inside ZAP	Outside ZAP	T23

In general, the 3rd and 4th class teachers moved towards the hypothetical ideal in relation to their confidence and implementation of the lessons. The teachers' progress varied, and although some teachers moved towards the ideal, they remained outside the ZAP at the end of term three. This indicates that these teachers require further support to improve their confidence and implementation of the lessons. However, not all teachers moved towards the ideal. T23 moved away from the ideal and out of the ZAP at the end of term three, in relation to her implementation and confidence. This is discussed in more detail in the next section. A matrix was created comparing the 3rd and 4th class teachers' change in implementation (Table 6.4) against their change in confidence (Table 6.5), as shown in Figure 6.9.

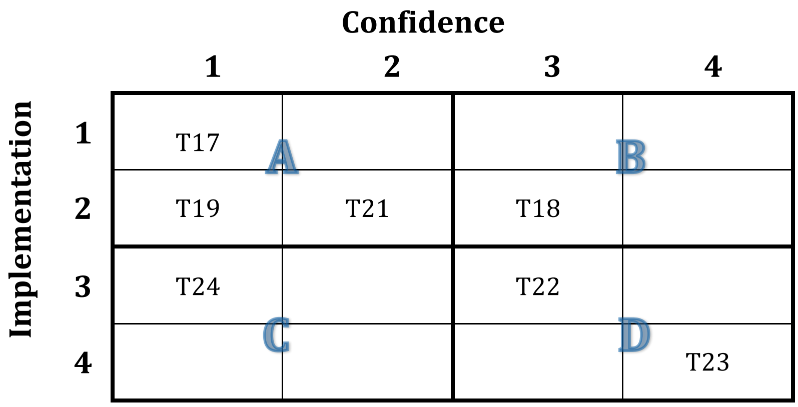

Figure 6.9: Classification of the 3rd/4th class teachers in relation to their implementation and confidence in teaching the CASE lessons

From Figure 6.9, four main groupings (A, B, C and D) were determined as described in Table 6.6. The teachers' confidence and success in implementing the lessons is discussed in more detail within these groups in the next section.

Table 6.6: General description of teachers in each group

Group	Teacher Description	Teachers
Group A (Upper left quadrant)	Teachers were confident and successful in their implementation of the lessons	T17, T19, T21
Group B (Upper right quadrant)	Teachers were successful in their implementation of the lessons, however they were not confident in their ability	T18
Group C (Lower left quadrant)	Teachers' were largely unsuccessful in their implementation of the lessons, however they are confident in their ability	T24
Group D (Lower right quadrant)	Teachers' were largely unsuccessful in their implementation of the lessons and teachers are not confident.	T22, T23

6.1.4 Analysis of 3rd and 4th Class Teacher Groups

The teachers were classified into four groups based on the MDS analysis of their overall change in confidence and implementation of the CASE lessons. Each individual group will now be discussed within the groups shown in Table 6.6.

Group A

Group A consists of T17, T19 and T21. Teachers in this group were considered confident and successful in their implementation of the lessons at the end of the programme. To gain a deeper insight into the progress made by each teacher, their implementation rating for each lesson was compared against their confidence, as shown in Figure 6.10. The teachers' implementation and confidence ratings were obtained as described in Chapter 4. The 'L' beside each point refers to the number of the lesson, which corresponds to the set of lessons presented in Table 6.2 and Table 6.3.

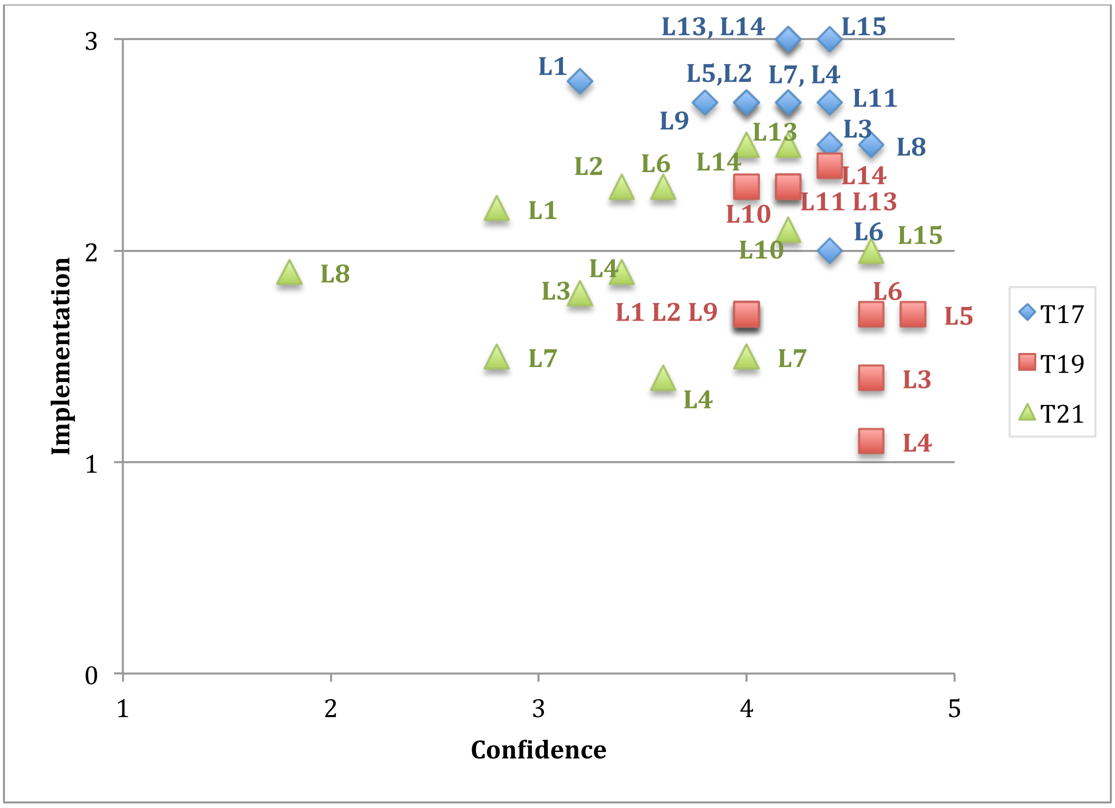

Figure 6.10: 3rd and 4th class teachers' (Group A) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.2 and Table 6.3. (Note: some points on the graph overlap)

At the end of term three, T17, T19 and T21's were confident and successful in their implementation of the CASE lessons. However, the trend of progression over each lesson differs for the three teachers. Figure 6.10 illustrates that:

- Excluding L1, T17 was consistently confident and successful in her implementation of the lessons,
- From the beginning of the programme, T19 was consistently confident in his ability to teach the lessons; however, this was not reflected in his implementation until the end of term three. T19's implementation of L1 -5 was largely unsuccessful, however, the teacher was confident in his ability. In the third term, T19 remained confident, but his implementation of the lessons improved. However, T19 could develop further in relation to his implementation.
- T21 improves in relation to her implementation and confidence from the beginning of the programme to the end. T21's progression is not linear and some of the lessons in the middle of the year are not implemented

successfully (L7 and L8). This is reflected in the teachers' confidence for these lessons. However, the last four lessons (L10, L13, L14 and L15) were all situated in the upper right quadrant, signifying that the teacher was successful and confident in her implementation.

This analysis suggests that the three teachers were generally successful and confident in their implementation of the CASE lessons at the end of term three. To explore the teachers' implementation of the lessons further, their implementation of each individual pillar was analysed. As previously discussed, the CASE lessons consist of 5 pillars. This section analyses the teachers' confidence and implementation of each individual pillar, from term one to term three. Again, the first and last three lessons were used as measures of the teachers' confidence and implementation at the beginning and at the end of the programme. The teachers' implementation and confidence of the three pillars of concrete preparation (CP), cognitive conflict (CC) and metacognition (M) are represented on Figure 6.11. As discussed in Chapter 4, the cognitive conflict includes both introducing the cognitive challenge and managing the social construction phase of the lesson, and these two aspects are analysed together. The teachers' implementation of each pillar at the end of the programme is denoted by an asterisk (*) beside the pillar, as shown in Table 6.7. The pillar of bridging is not included in this analysis as, although there was an item asking teachers to describe their implementation of this pillar, there was no corresponding item asking teachers how confident they felt in their implementation. The teachers' implementation of this aspect of the lessons will be discussed separately in Section 6.6.

Table 6.7: Notation used to represent each pillar of the CASE lessons for term 1 and term 3

Pillar	Term 1	Term 2
Concrete Preparation	CP	CP*
Cognitive Conflict	CC	CC*
Metacognition	M	M*

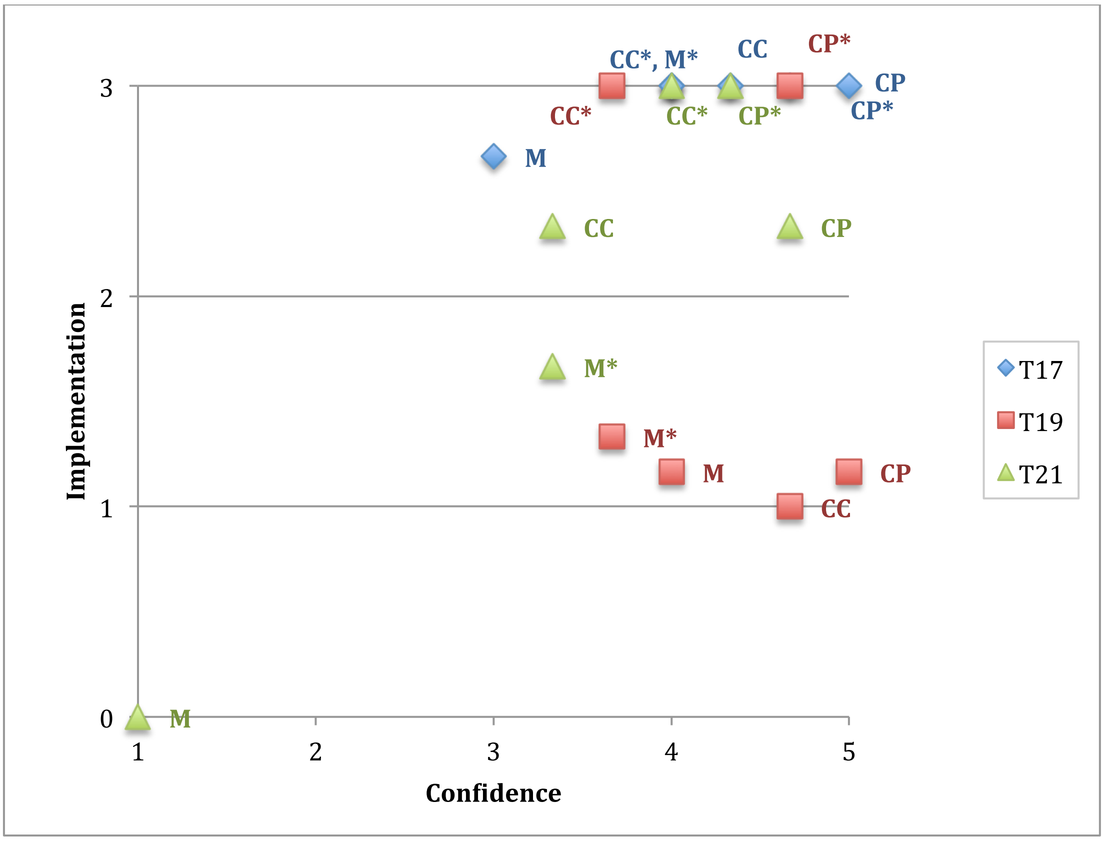

Figure 6.11: 3rd and 4th class teachers' (Group A) implementation versus confidence for each pillar. Notation described in Table 6.7.

All three teachers improved in their ability to implement the pillars of the CASE lessons from term one to term three, as shown by Figure 6.11. T17 was consistently successful in her implementation of each pillar. T17 was slightly less confident in her implementation of the pillar of metacognition at the beginning of term one but this improved towards the end of term three.

T19 generally improved in his implementation of the pillars of concrete preparation and cognitive conflict from term one to term three. At the end of term three, T19's implementation of the pillars of concrete preparation and cognitive conflict was successful. T19's confidence does decrease slightly in relation to both aspects, however he remained largely confident. T19's implementation of the pillar of metacognition was unsuccessful throughout the programme.

T21's confidence decreased slightly from the beginning of term one to the end of term three. At the beginning of the year, T21 was reasonably successful in her implementation of the pillars of concrete preparation and cognitive conflict, and the teacher improved in this as the programme progressed. At the end of term three, T21 was generally confident in relation to both aspects. T21's implementation of the pillar of metacognition was entirely unsuccessful in term one and the teacher was not confident. T21's confidence and implementation of this pillar improved in term three, however her implementation remained largely unsuccessful.

Group B

Group B consists of T18, as shown in Table 6.6. Teachers in this group were successful in their implementation of the lessons at the end of the programme, however they were not very confident. Figure 6.12 presents T18's implementation versus her confidence for each lesson. In term one, T18's implementation of the lessons was generally unsuccessful and she was not very confident. During the year, T18 improved in relation to both aspects, however, this progress was not linear. T18's implementation and confidence varied throughout the programme although the later lessons implemented by T18 were generally more successful than at the beginning. Despite an increase in confidence during the programme, T18 was not entirely confident in her implementation of most of the lessons.

Again, the teachers' confidence versus implementation for each pillar was analysed as shown in Figure 6.13. T18 improved in her implementation for all pillars of the CASE lessons. At the beginning of term one, T18 was only successful in her implementation of the pillar of concrete preparation. T18 was unsuccessful in her implementation of the pillars of cognitive conflict and metacognition, which was mirrored in her confidence. Towards the end of the programme, T18's implementation of the pillar of cognitive conflict improved, and the teacher was largely successful, however the teacher's confidence decreased slightly. Towards the end of the programme, T18's implementation of the pillar of metacognition improved, as did her confidence. However, the teacher remained unsuccessful in her implementation, and could progress further in relation to both aspects.

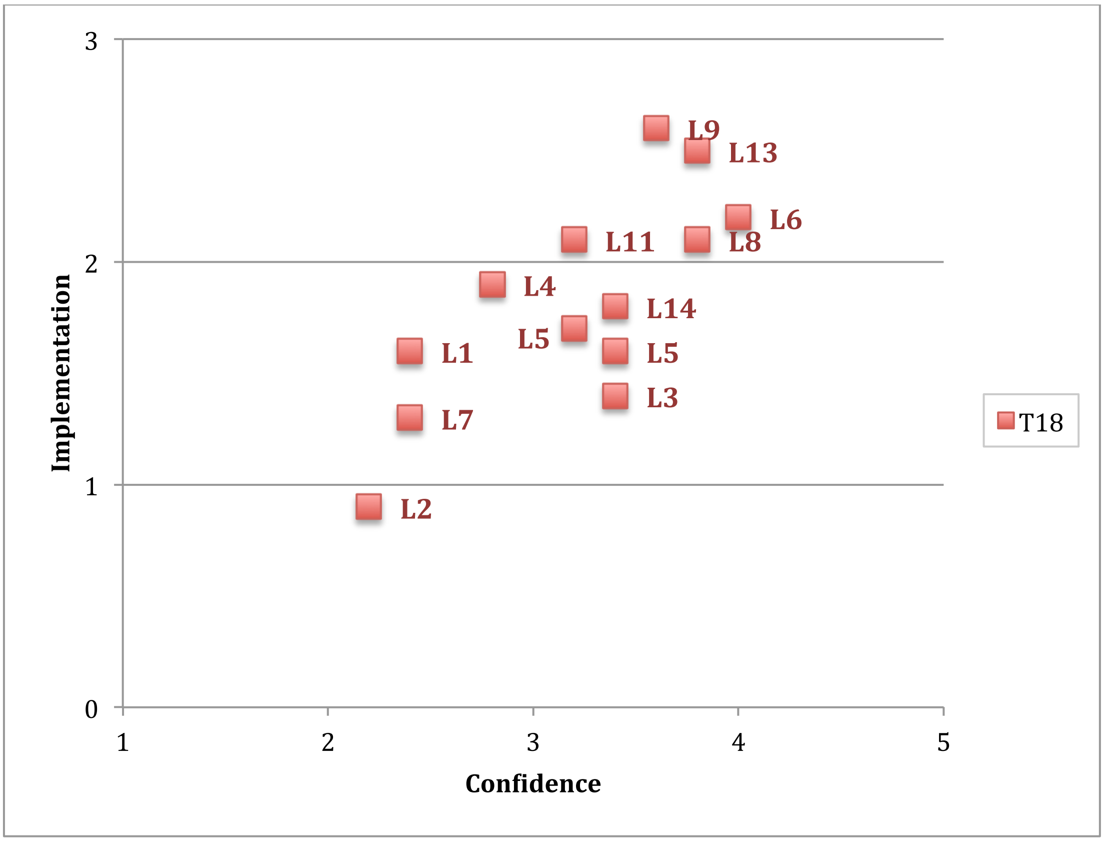

Figure 6.12: 3rd and 4th class teachers' (Group B) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.2.

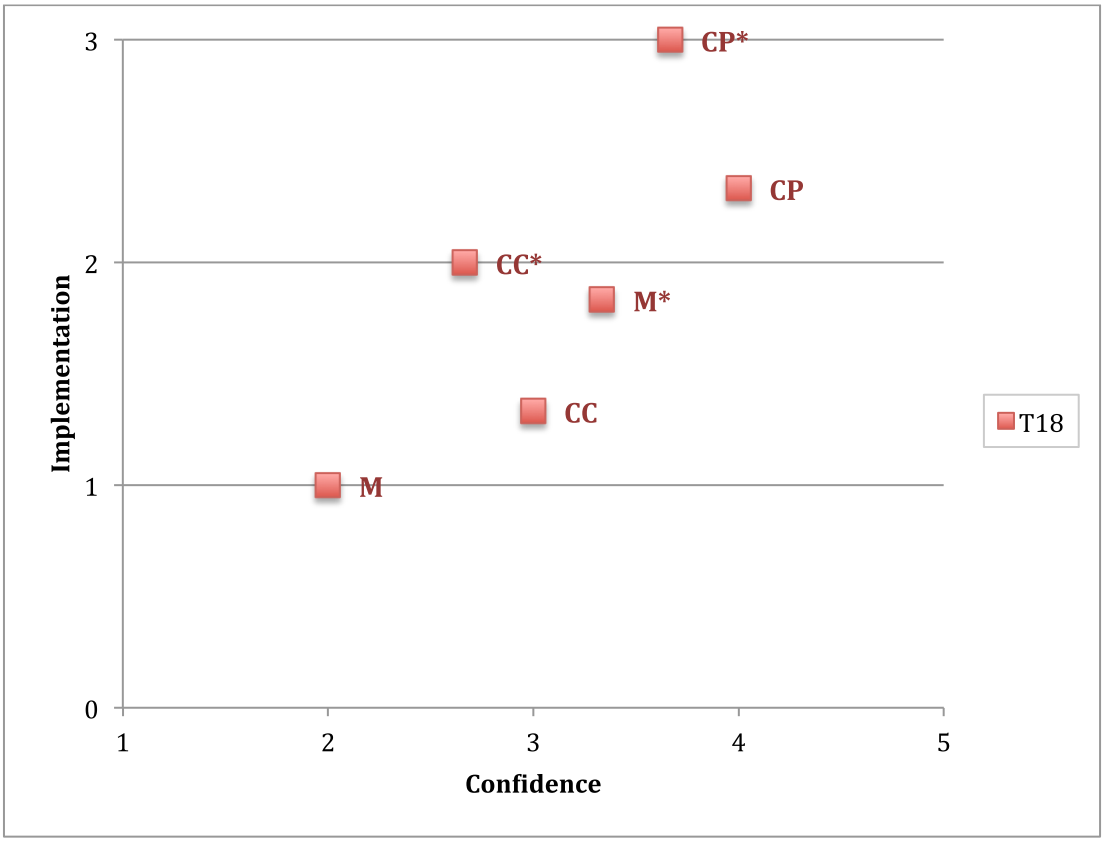

Figure 6.13: 3rd and 4th class teachers' (Group B) implementation versus confidence for each pillar. Notation described in Table 6.7.

Group C

Group C consists of T24, as shown in Table 6.6. T24 was consistently confident in his ability to teach the CASE lessons, despite being largely unsuccessful in his implementation, as shown in Figure 6.14. L13, the last lesson implemented by the teacher, was implemented with reasonable success, however this improvement was not consistent over all of the lessons, and T24 remained over confident.

T24 was also over-confident in his ability to implement all of the pillars of the CASE lessons, as shown in Figure 6.15. The teacher improved in his ability to implement the pillars of concrete preparation and cognitive conflict however, at the end of the programme, this remained largely unsuccessful. T24's implementation of the pillar of metacognition was unsuccessful at the beginning of term one, and decreases further at the end of term three.

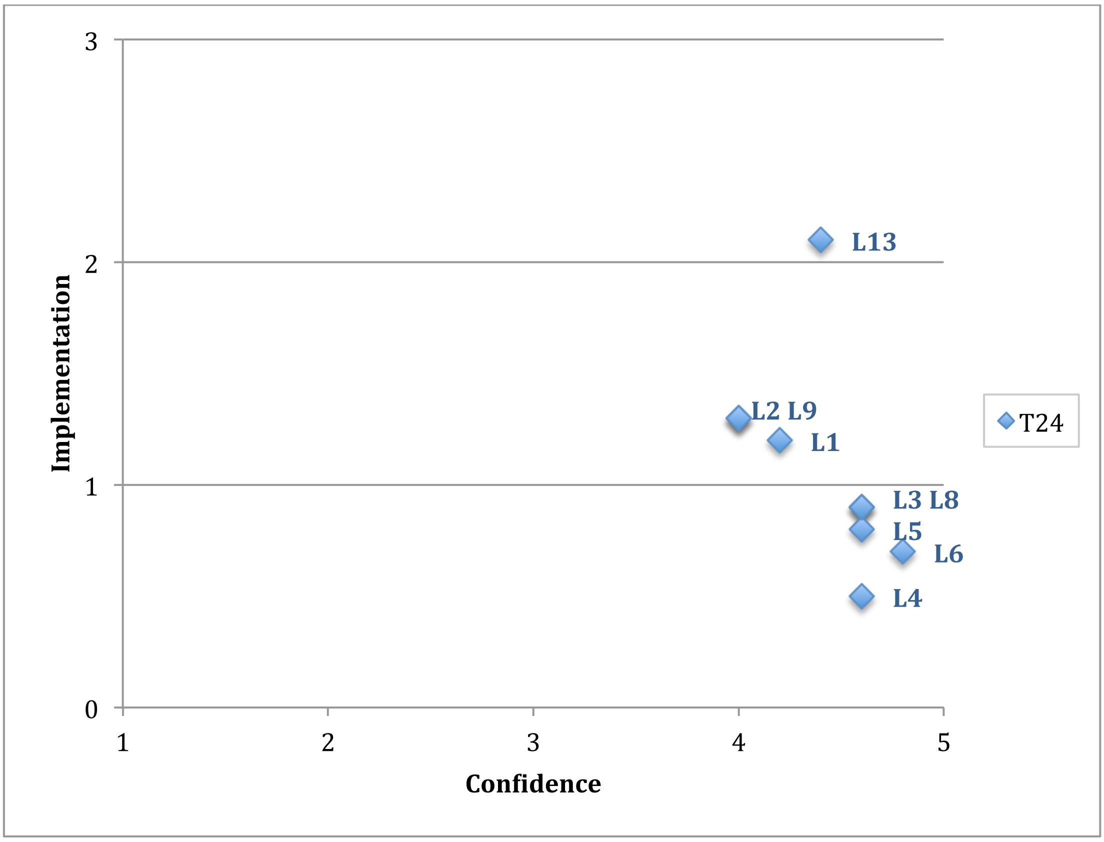

Figure 6.14: 3rd and 4th class teachers' (Group C) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.3.

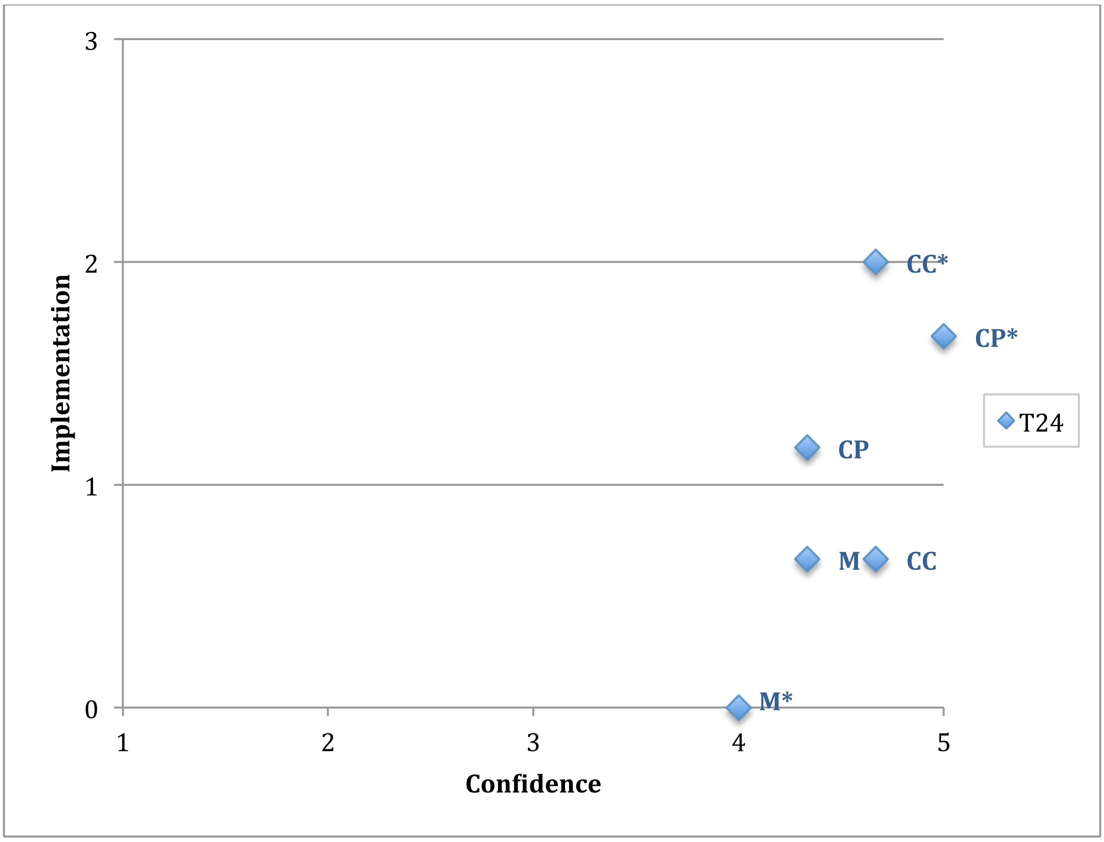

Figure 6.15: 3rd and 4th class teachers' (Group C) implementation versus confidence for each pillar. Notation described in Table 6.7.

Group D

Group D consists of T22 and T23. Teachers in this group were generally not very confident or successful in their implementation of the CASE the lessons at the end of the programme. In general, T22 and T23's implementation of the CASE lessons was unsuccessful and the teachers were not very confident. T22 did display a slight increase in confidence from the beginning of the programme, however her implementation remained unsuccessful. The last lesson, L13, was implemented reasonably successfully, as shown in Figure 6.16, however the teacher displayed no overall trend of improvement from the beginning of the programme to the end. Overall, T23 does not make any significant improvement in relation to her confidence or implementation of the CASE lessons. T23 was reasonably successful in her implementation of the lessons at the beginning of term one, however, the teachers' implementation of later lessons, (L9, L10 and L13) was unsuccessful. T23's confidence also decreased as the programme progressed. The last lesson implemented, L14, was reasonably successfully, however, the teacher was not consistent, as shown in Figure 6.16.

In relation to the implementation of each pillar of the CASE lessons, T22 was reasonably successful in her implementation of the pillar of concrete preparation throughout the programme, as shown in Figure 6.17. In term one, T22 was unsuccessful in her implementation of the pillars of cognitive conflict and metacognition, and she was not very confident. In term three, T22's implementation of the pillar of cognitive conflict improved and she was generally successful. T22 also improved in her implementation of the pillar of metacognition, however this remained largely unsuccessful throughout the programme and the teacher was not very confident. At the beginning of term one, T23 was not very successful in her implementation of the pillars of concrete preparation and cognitive conflict, however the teacher was confident. The teacher was successful in her implementation of the pillar of metacognition in term one, although the teacher was not very confident. In term three, T23 improved in her implementation of the pillars of concrete preparation and cognitive conflict, however the teachers' confidence decreased slightly. The teacher's confidence and implementation of the pillar of metacognition decreased and was largely unsuccessful at the end of the programme.

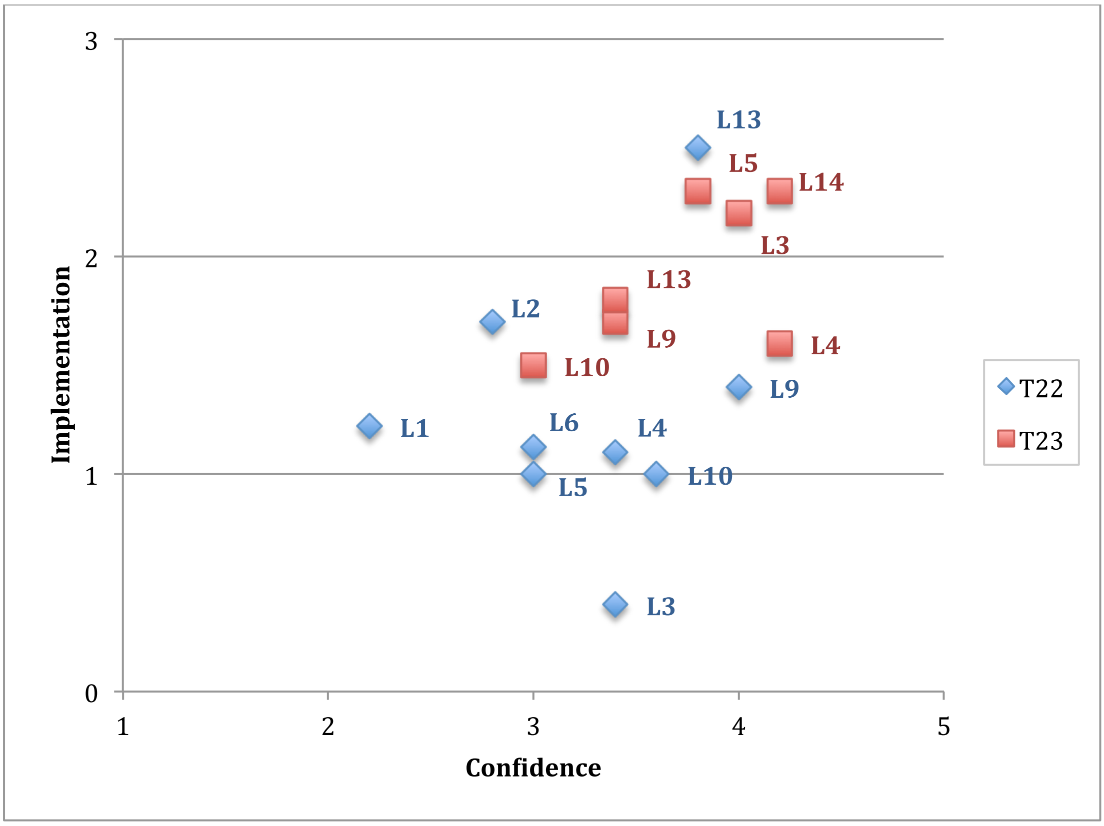

Figure 6.16: 3rd and 4th class teachers' (Group D) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.3.

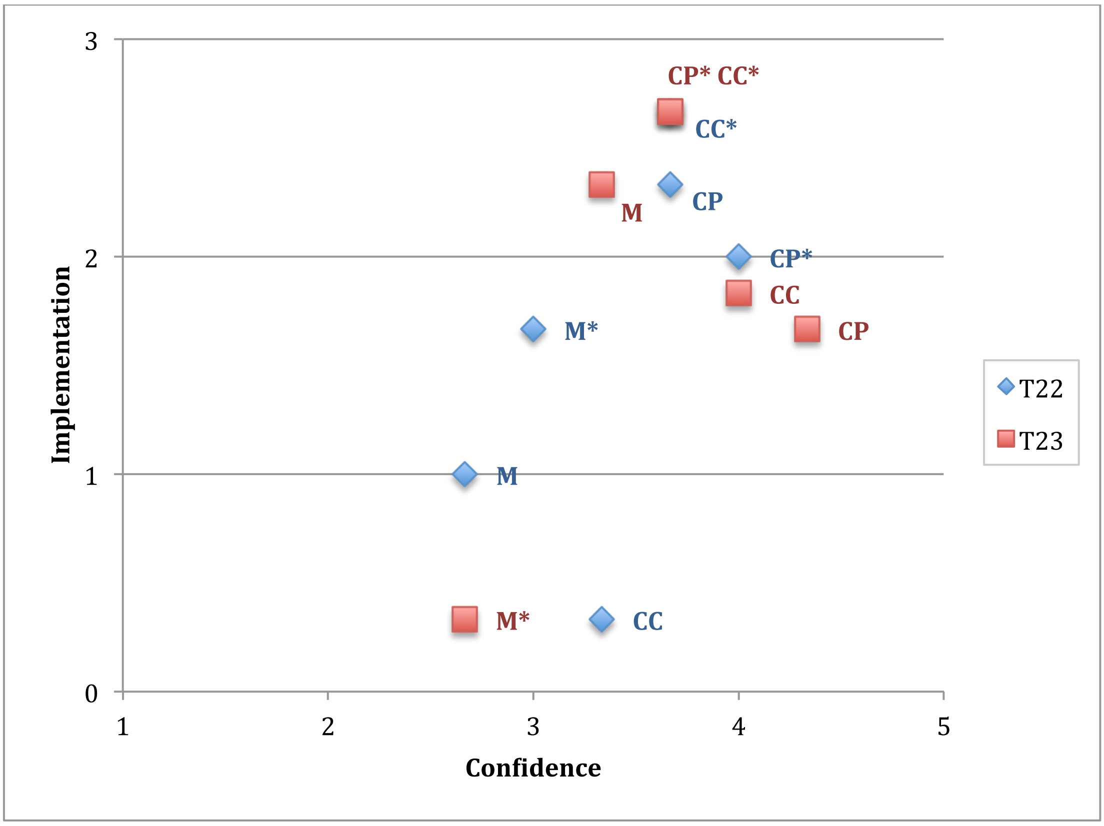

Figure 6.17: 3rd and 4th class teachers' (Group D) implementation versus confidence for each pillar. Notation described in Table 6.7.

Summary

In general, the teachers improved in their implementation of the CASE lessons throughout the programme. T17, T18, T19 and T21 were largely successful in their implementation of the lessons at the end of term three. T22 and T24 also improved in their implementation, although both teachers could progress further. The MDS analysis of T23's responses to the lesson reflections suggests that the teachers' implementation of the lessons decreased throughout the programme. However, the analysis of the teachers' implementation of each pillar of the lessons (Figure 6.17) highlights that the teachers' implementation of the pillars of concrete preparation and cognitive conflict improved, and it was the teachers' implementation of the pillar of metacognition that decreased. T18, T19, T21, T22 and T24 were also unsuccessful in their implementation of this pillar throughout the programme. T17 is the only teacher who is consistently successful in her implementation of this pillar. The remaining teachers made very little, if any, improvement in their ability to implement the pillar of metacognition, which was largely unsuccessful throughout the programme.

The teachers' confidence in their implementation also varied. T17, T19 and T21 were both confident and successful in their implementation at the end of the programme. T24 was also consistently confident although this did not always agree with the teachers' implementation of the lessons. This may suggest that the teacher does not fully understand the CASE methodology and requires further support in implementing the lessons. T18, T22 and T23 were generally not very confident in their implementation of the lessons; however, this lack of confidence primarily concerns the pillar of metacognition. All of the teachers require further support in their implementation of this pillar, which will be discussed in more detail in Chapter 7.

The analysis of the teachers' implementation of the lessons described thus far has been based upon the teachers' responses to the written lesson reflections. The next section considers the researcher's observations to determine whether they correlate with the teachers' responses to the lesson reflections.

6.1.5 Researcher Observations

To assess the validity of using the teachers' responses to the lesson reflections as a measure of their implementation, their ratings generated from the lesson reflection was compared with the researcher's observations. The researcher rated the teachers' implementation of a number of aspects of the lessons on a scale of 1-5, as described in Section 4.2. The aspects rated by the researcher during observations correspond with the teachers' self-rating in the lesson reflections. From this, an overall observation rating could be obtained for each lesson observed, which is the researchers' rating of how successful the teacher was in implemented the lesson. The 3rd and 4th class teachers were observed between 3 and 7 times. The teachers' implementation rating for each lesson versus the researcher's observation rating were compared, as shown in Figures 6.18 and 6.19.

The relationship between the 3rd class teachers' implementation and their observation rating is shown in Figure 6.18. Each point represents a lesson implemented by a 3rd class teacher. The blue line highlights the relationship between the two aspects. If the teachers' implementation rating for a lesson generally agrees with the researcher's observation rating, then the lesson will be situated close to the blue line. Figure 6.18 suggests that, in general, the 3rd class teachers' reflections agree with the researchers observations. There are, however, a number of outlying points, which indicates that there is a degree of variance between the teachers' lesson reflection responses and the researchers observations for those lessons. Observation ratings for L1 implemented by T17, and L6 and L11 implemented by T18 are lower than the implementation rating obtained from the analysis of the teachers lesson reflections, as shown in Figure 6.18. This indicates that these lessons were not as successful as indicated by the teacher's responses to the lesson reflections. In addition, researcher observations for L3, L4 and L6 implemented by T19 indicate that these lessons were more successful than indicated by the teachers' responses to the lesson reflections, as shown in Figure 6.18.

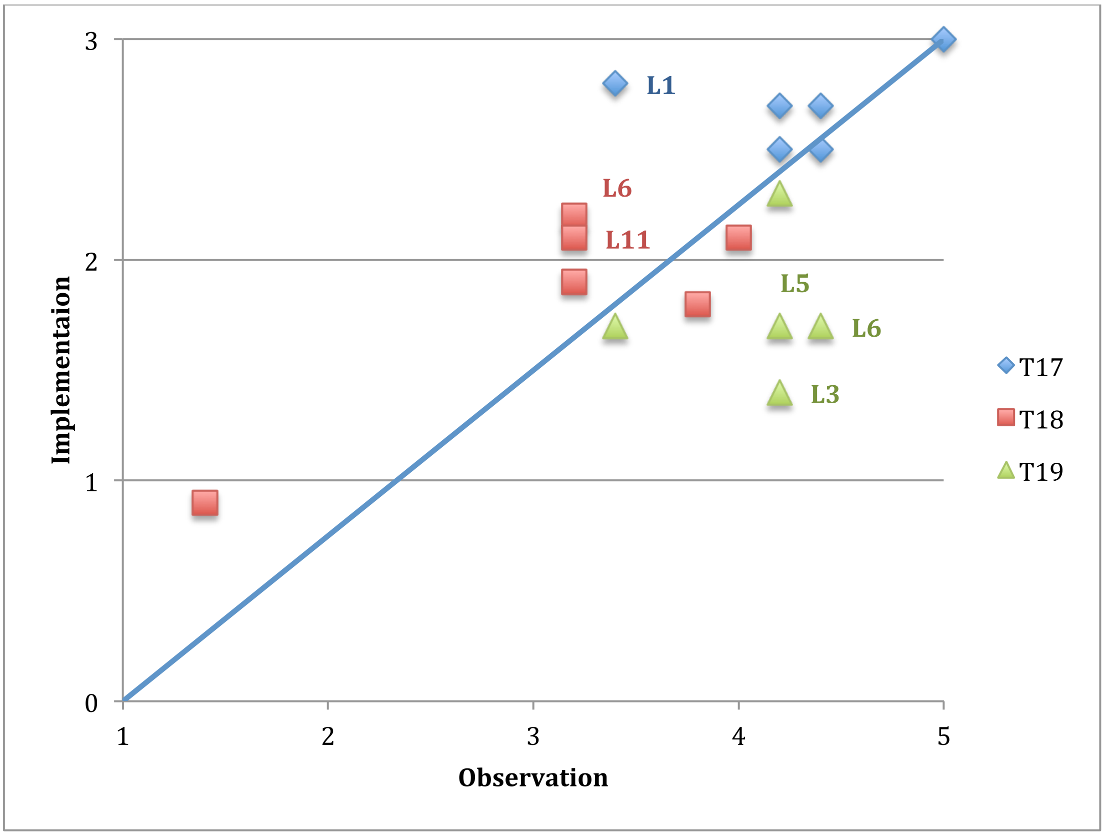

Figure 6.18: Researcher observations versus lesson implementation rating generated from the 3rd class teachers' responses to the lesson reflections

If it is assumed that the researcher's observations are a more accurate assessment of how successful the lesson implementation was, then the observation rating can be substituted in place of the teachers' implementation rating derived from the lesson reflections for the outlying points in Figure 6.18. The teachers' responses to the lesson reflections were scaled from 0 to 3, with a rating of 0 indicating that the implementation was entirely unsuccessful, and a rating of 3 being entirely successful. However, researcher observations were rated on a scale of 1 to 5. By converting the researcher's observation to a scale of 0-3, it can be substituted in place of the teachers' implementation rating generated from the lesson reflection. For example, the implementation rating obtained from T17's lesson reflection does not agree with the researchers observation rating for lesson 1. From the lesson reflection, T17's implementation for the lesson overall was evaluated at 2.8 out of 3, indicating that the teacher's implementation was largely successful. However, the researcher's observation indicates that the teacher's implementation of the lesson was slightly less successful and was rated at 3.4 on a scale of 1 to 5. If the observation value is converted to a scale of 1 to 5, it can be substituted in place of the value generated from the lesson reflection and the point shifted, as shown in Figure 6.19. The asterisk beside the lesson number signifies the implementation rating generated from the researcher's observations. This movement indicates that T17's implementation of L1 was not as successful as described in the teacher's responses to lesson reflection. The same method can be applied to T18's implementation of L6 and L11, and the points shifted, as shown in Figure 6.19.

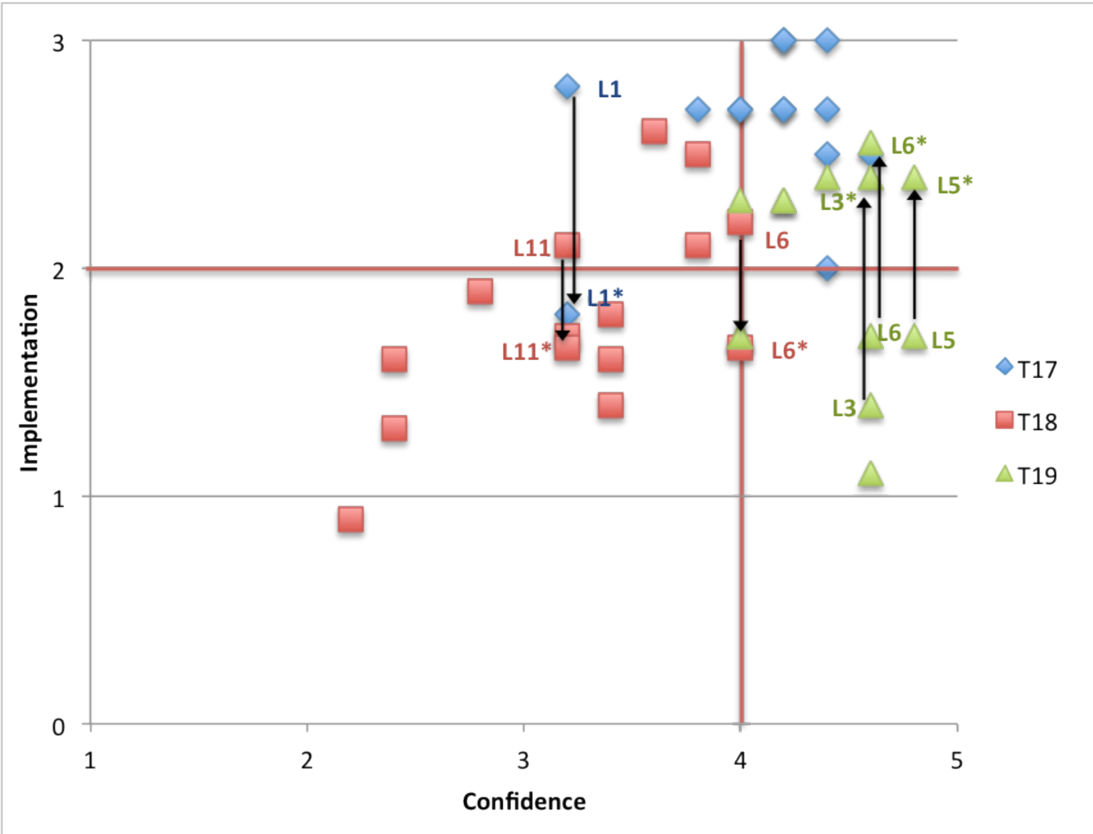

Figure 6.19: 3rd class teachers' implementation of the CASE lessons using the researcher's observation rating in place of the rating generated from the lesson reflections. The asterisk (*) beside the lesson code signifies the implementation using the researcher's observation.

Although the points have shifted, the general trend of progression for both teachers has not been altered significantly. T17's implementation of the lessons remains largely successful throughout the programme, while T18's implementation of the lessons improved and was generally successful at the end of the programme. Both teachers remain within the groups to which they were assigned in Figure 6.9 and Table 6.6. In addition, the number of outlying points is relatively small in comparison with the number of points that agree for these teachers. For example, T17 was observed on six occasions and only one observation rating does not agree with the teachers' implementation as described in their lesson reflections. However T19 was observed on five occasions and three of the observation ratings for this teacher do not agree with the teacher's responses to the lesson reflections. If the researcher's observation ratings are substituted in place of the rating generated from the lesson reflections as described above, L3, L5 and L6 appear to have been implemented reasonably successfully by the teacher. This indicates that T19's implementation of the lessons was generally more successful than suggested by his responses to the lesson reflections and implies that the lesson reflections may not be an accurate account of the T19's implementation of the lessons. However, this movement of points does not alter the teachers classification at the end of the programme as the teacher is in Group A in Figure 6.9, signifying that the teacher was largely successful in his implementation at the end of the programme.

The same analysis was carried out on the 4th class teachers' implementation of the lessons, as shown in Figure 6.20. In general, the 4th class teachers' implementation rating obtained from their lesson reflections agreed with the researcher observations. However, the researcher observations for T22's implementation of lesson 4 indicate that the teacher's implementation was more successful that suggested by the lesson reflection.

The researcher's observation rating was converted to a scale of 0 to 3, as described above, and the point moved as shown in Figure 6.21**.** Again, this movement does not significantly alter the teacher's general trend of progression, and T22's implementation remains largely unsuccessful at the end of term three. Due to the relatively small number of outlying points, the teachers own reflections were considered a reliable measurement of how successful the lesson implementation was.

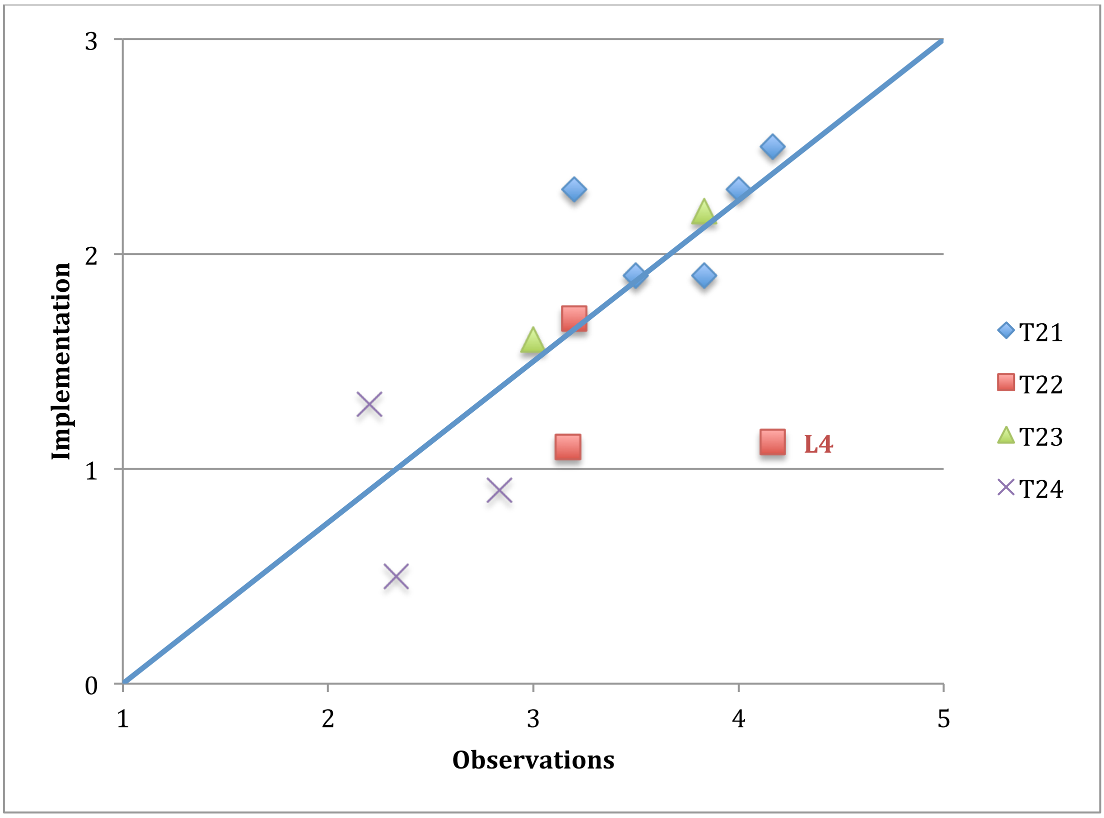

Figure 6.20: Researcher observations versus lesson implementation rating generated from the 4th class teachers' responses to the lesson reflections.

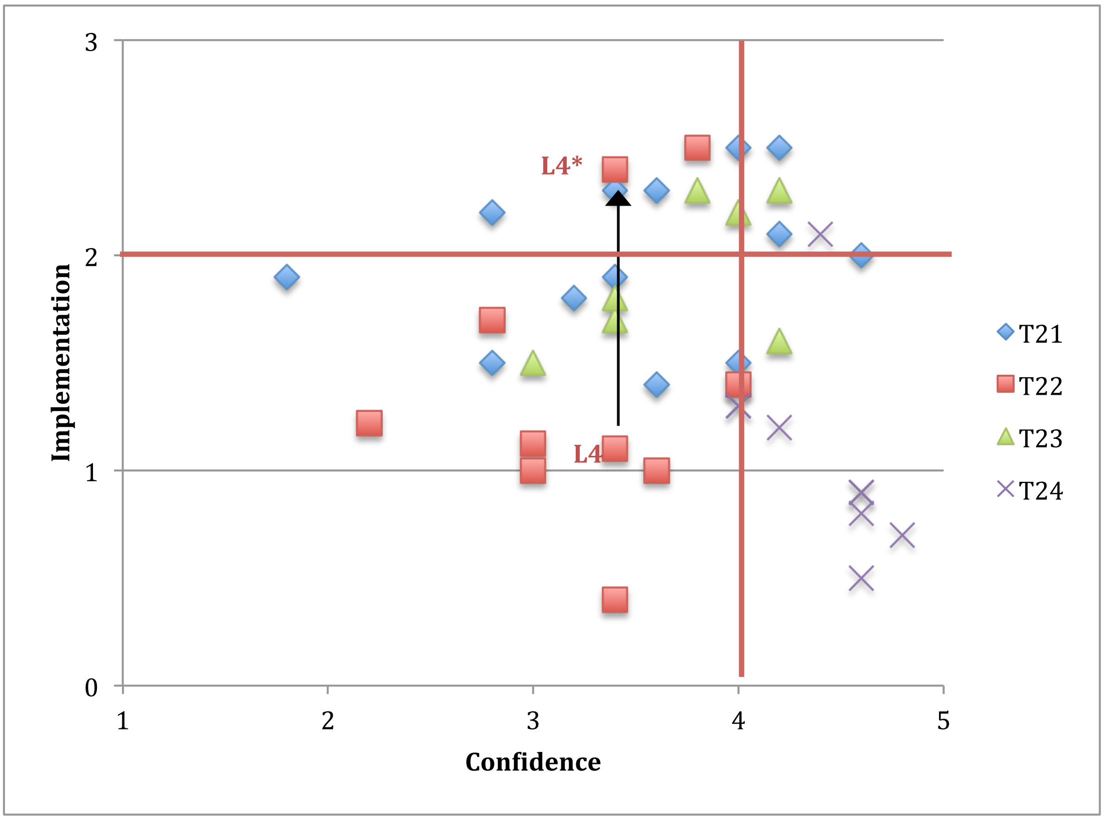

Figure 6.21: 4th class teachers' implementation of the CASE lessons using the researcher's observation rating in place of the rating generated from the lesson reflections. The asterisk (*) beside the lesson code signifies the implementation using the researcher's observation.

6.1.6 3rd and 4th teachers' confidence in their understanding of the science content in the CASE lessons

In the lesson reflections, the teachers were asked to rate their confidence in their understanding of the scientific content covered in the CASE lessons on a scale of 1 to 5, with 1 being not confident and 5 being very confident. The teachers' confidence in their understanding of the science content in the lessons was graphed against the teachers' implementation rating generated from their lesson reflections to analyse whether the teachers' confidence in their understanding of the science content had any effect on their implementation of the lessons. The 3rd and 4th class teachers' confidence in the science content knowledge versus their implementation for each lesson is shown in Figures 6.22 and 6.23 respectively. The lessons in which the teachers were not very confident in their understanding of the science content are highlighted on the graph.

Figure 6.22 indicates that T17 and T19 were generally confident in their understanding of the scientific content in the lessons. T17 was not very confident in her knowledge of the science content covered in L9 (*How hot are you*?), which is the first of four lessons on the topic of heat. However, the teacher was confident in the science content in the other three lessons on the same topic. Despite her lack of confidence, T17 was successful in her implementation of the lesson. T19 was also generally confident in his understanding of the science content in the lessons, although he was not very confident in his understanding of the content covered in L5 (*What makes me move?*). Despite this, the researcher observations for this lesson indicate that he was successful in his implementation. T18 was generally not very confident in her knowledge of the science content covered in the CASE lessons. T18 rated her confidence as a 1 out of 5 for the introductory lessons L1 and L2. These lessons do not cover any science content and suggests that the teacher was not very confident with the CASE methodology rather than any science content. The teacher's confidence appears to have improved slightly as the programme progressed, however the teacher was not very confident. T18 was confident in her science content in lessons L6 and L8, which focus on the topic of animal habitats. Chapter 5 highlighted that the teachers in this study were generally very confident teaching the strand Living Things.

The 4th class teachers were generally confident in their content knowledge, as shown in Figure 6.23. T21's confidence in her knowledge of the science content varied for each lesson, however this does not appear to have had an effect on her implementation. For example, T21 was not very confident in her scientific understanding regarding lessons L14 and L15, which focus on the topic of electricity. However, the teacher was successful in her implementation of both lessons. T22, T23 and T24 were largely confident in their understanding of the science content covered in the lessons, as shown in Figure 6.23. T22 was not very confident in her knowledge of the science content in introductory activity L1 (*Climb that mountain*). Again, this lesson does not cover any science content and suggests that the teacher was not confident with the CASE methodology, rather that any scientific content.

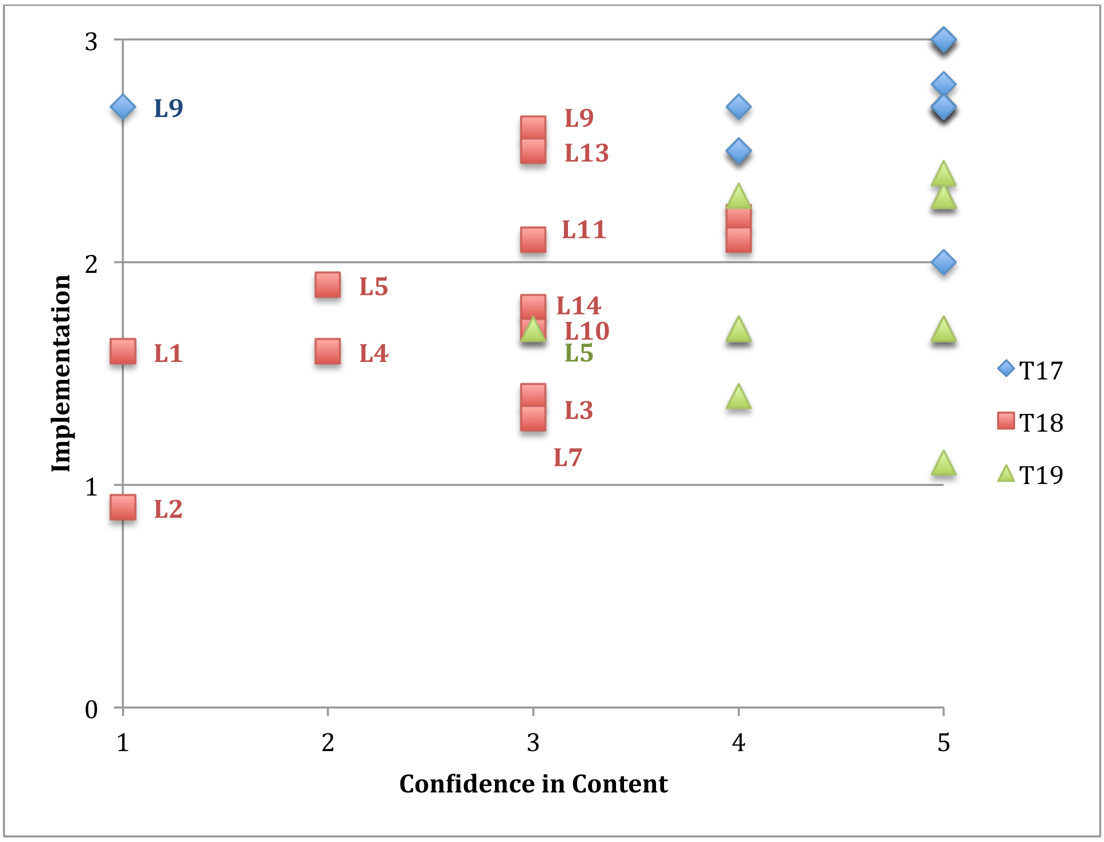

Figure 6.22: 3rd class teachers confidence in their understanding of the science content covered in the lessons versus their implementation

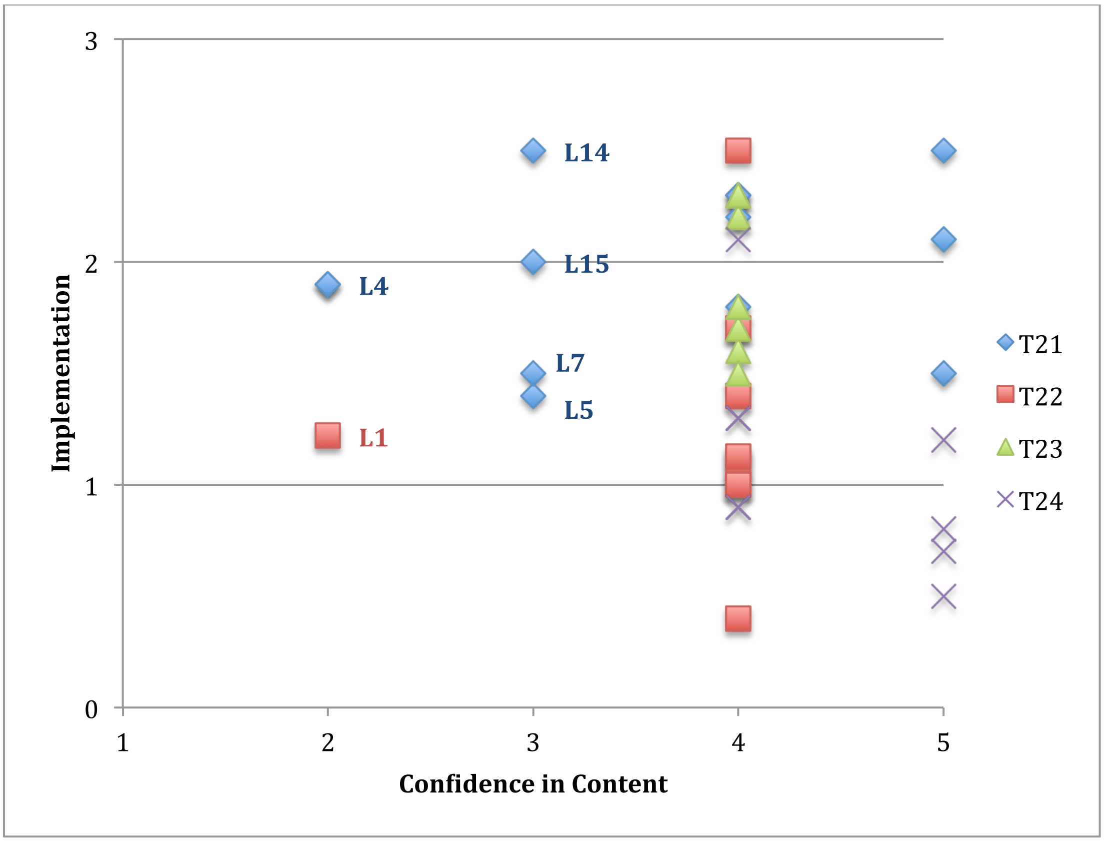

Figure 6.23: 4th class teachers confidence in their understanding of the science content covered in the lessons versus their implementation

The 3rd and 4th class teachers were generally confident in their knowledge of the science content in the CASE lessons. T18 and T21 were slightly less confident in their science understanding, than the other teachers. Overall there did not appear to be a direct relationship between the teachers' implementation and confidence in their understanding of the science content in each lesson. It must be noted that this is a teacher's self-rating of their knowledge of the scientific content in the lessons and not an actual measure of the scientific understanding. A teacher may have a sound knowledge of the scientific concepts covered in the lesson but not consider themselves confident and vice versa.

6.1.7 The 3rd and 4th class teachers and the CASE methodology overall

This section provides an overview of the 3rd and 4th class teachers' engagement with the CASE methodology. Data sources include teachers' responses to Q2, Focus Group discussions and researcher observations. T19 and T20 participated in Focus Group discussions but did not respond to Q2.

- **3rd Class Teachers**

The teachers generally had a positive attitude towards the CASE methodology, with the 3rd class teachers slightly more positive than the 4th class teachers. T17 and T18 (3rd class teachers) rated the CASE methodology very highly as it focused on developing students' "science skills" rather than focusing on the content (T17.Q2). Both teachers referred to their role as facilitator, asking questions to help students to construct their own knowledge, rather than providing answers.

> *"The teacher's role differs in that student and teacher work together. Teachers ask guided questions but do not offer solutions as much as in other classes"* (T17.Q2)

Both teachers were confident in their understanding of the CASE methodology and in their ability to implement the lessons at the end of the year; however, T18 felt that she could improve further in relation to this (Q2). This agrees with the teacher's classification in Figure 6.9 (Group B) indicating that she was not very confident in her ability to implement the lessons. T17 felt that her confidence improved through "seeing how the pupils worked together, shared their ideas and knowledge and began to reflect on their thinking and learning" (T17.Q2).

T17 considered all of the pillars of the CASE methodology important in their own way but felt that the pillar of metacognition was the most important as it allowed the students to reflect on their thinking and how they came up with solutions. She felt that this was the biggest difference between the CASE lessons and other science lessons she has taught (T17.Q2). The teacher also found this pillar the most difficult aspect of the lesson to implement, however she stated that "once I saw the value of it, and how the students responded, it became easier" (T17.Q2). T17's engagement with the pillar of metacognition was reflected in her implementation, and she was the only teacher who was able to engage her students in metacognitive discussions throughout the programme. She states that encouraging her students to reflect on their decision-making and thinking is a skill that she will incorporate into her future teaching (Q2). T17 also felt that she developed the ability to guide her students rather than providing answers as a result of teaching the CASE lessons (T17.Q2). T18 considered the pillar of cognitive conflict the most important pillar of the lesson as it "stimulates the students into a thinking zone based on their prior knowledge and provides a platform for sharing and collaboration learning" (T18.Q2). The teacher also felt that her ability to 'bridge' the thinking the students engaged in during a CASE lesson, to other areas of her teaching, had improved from the beginning of the programme. T18 felt that she was more prepared and more confident in her teaching of science as a result of teaching the CASE lessons.

In relation to the scientific content in the lessons, T17 was confident in her understanding, however T18 was not very confident. This agrees with the teachers' confidence in their understanding of the science content as discussed in Section 6.1.8. Researchers observations for T18 indicate that, at the beginning of the programme, the teacher's lack of science content hindered her implementation of the lessons. The teacher tended to focus on the science content in the lesson rather than on the students' thinking; however, T18 did improve at this as the programme progressed. Both teachers felt that their own scientific content knowledge improved through implementing the CASE lessons and the lessons they will be easier to implement next year, however T18 felt that she needed to improve her scientific content knowledge further.

Both teachers felt that their students enjoyed the CASE lessons, particularly the cognitive conflict as it "challenged them" (T17.Q2). T17 considered the pillar of metacognition the most difficult aspect of the lesson for her students; however, she felt that they improved as "they became more familiar with the process and more confident in their opinions and abilities" (T17.Q2). T18 felt that her students tended to focus on the 'one right answer' but through encouragement from herself and the researcher, they began to accept that an answer could be right once they had sufficient evidence and could provide an explanation (T18.Q2). Both teachers felt that their students' abilities to work in pairs, think for themselves, not focus on the one right answer and verbalize their thought processes, had improved as a result of engaging with the CASE lessons.

- **4th Class Teachers**

The 4th class teachers also had a positive attitude towards the CASE methodology. The teachers felt that the students "*had to do more thinking than in other lessons*" (T23.Q2), and encouraged students to develop their scientific skills and ability to think metacognitively (T21.Q2). However, the 4th class teachers felt the early lessons (L1-L8) were not challenging enough for their students, which made it difficult to engage them in meaningful discussions about their thinking (FG4). T21 found that the later lessons (L9-L15) were more challenging for her students and that they were better able to engage with the metacognition aspect of the lessons (T21.Q2). As previously mentioned in Section 6.1.1, lessons 1-8 completed by the 4th class students were originally part of the 3rd class programme and may explain why there was no significant cognitive conflict for the students.

T24's response to Q2 indicate that he was confident in his understanding of the CASE methodology and his ability to implement the lessons, which agrees with his classification in Figure 6.9. The teacher felt that his confidence increased by observing "*positive results from the students*" which gave him and the students a "*sense of achievement*" (T24.Q2). However, the teacher's responses to the lesson reflections and researcher observations, indicate that the teacher's implementation of the lessons was often unsuccessful. T24, who participated in the pilot study, tended to prematurely reveal the outcome of the lessons to his students, which removed the cognitive conflict and prevented his students from engaging in any meaningful thinking. The teacher's implementation of the lessons was similar during the pilot programme, indicating that the teacher did not improve in his implementation during the whole-school implementation phase of the study. This suggests that T24 requires further support to develop his understanding of the CASE methodology and his delivery of the lessons.

T21, T22 and T23 were not very confident in their understanding of the methodology or in their ability to implement the lessons successfully. However, T21 and T23 felt that their confidence had increased through improvements in questioning skills (T21.Q2) and engagement in team-teaching with the researcher (T23.Q2). T21, T22 and T23 considered the pillars of cognitive conflict and social discussion the most important aspects of the lessons as they "*challenge the students thinking*" (T22.Q2). All three teachers considered the pillar of metacognition the least important and most difficult aspect of the lessons. T21 felt that the questions in this section of the lesson plan had already been asked during the lesson and that it became repetitive. She also felt that her lack of understanding of the concept of metacognition prevented her from engaging her students in metacognitive thinking (T21.Q2). T23, whose implementation of this pillar of the lesson decreased from term 1 to term 3 (Figure 6.17) referred to a lack of confidence in her ability to guide her students through this pillar and that, as the students were unfamiliar with the concept, it was difficult to engage them in metacognitive thinking. The teachers' implementation of the pillar of metacognition is discussed in more detail in the Chapter 7.

The teachers felt that they were more confident in managing group-work and in challenging the students' thinking as a result of teaching the CASE lessons (T22.Q2 and T23.Q2). T21 felt that her questioning skills and ability to facilitate group discussions had improved.

> *It has changed my approach to facilitating investigations. I am more conscious about giving the children greater autonomy and time during their discussions and investigations. I am better at asking leading and guiding questions without giving too much information* (T21.Q2)

The teachers' responses to the lesson reflections indicates that the teachers were generally confident in their understanding of the science content, as described in Section 6.1.8. This analysis highlighted that only T21 was not very confident in her scientific understanding of some of the lessons. However, Focus Group discussions and researcher observations indicate that the 4th class teachers struggled with the science content in the topics of Forces and Electricity (L9-L15). The content in these lessons was covered in detail with the teachers during focus group discussions and the teachers were reasonably successful in their implementation of the lessons. T21, T23 and T24 felt that their own science content knowledge had improved as a result of teaching the CASE lessons and all four teachers felt that the lessons will be easier to teach next year (Q2). However, the teachers would like additional background information on these topics.

The 4th class teachers stated that their students enjoyed the CASE lessons, particularly those that incorporated a practical element (Q2). The teachers felt that their students improved in their ability to work in groups and to listen to others opinions (FG6). T24 felt that his students found it difficult to "*find valid reasons to back up their answers*" but improved at this as the programme progressed (T24.O2). In their responses to Q2, T21, T22 and T23 considered the pillar of metacognition the most difficult aspect for their students, as they didn't understand the concept or what they were being asked to do. T21 felt that her students improved in this as the programme progressed, as the lessons were more challenging. T23 felt that her students understanding of the concept improved during the programme but they still struggled to reflect on their thinking.

Overall

The 3rd and 4th class teachers improved in their implementation of the lessons during the programme. The teachers felt that their questioning skills had improved, and that they were better able to guide their students through the cognitive conflict and social construction aspects of the lesson. The 4th class teachers found the pillar of metacognition the most difficult aspect of the lesson and this was mirrored in their implementation. This is discussed in more detail in the next chapter.

As the programme progressed, the teachers began to integrate elements of the CASE methodology into other areas of their teaching. The teachers used the schema of classification in art (T18.L6), and seriation in mathematics (T21.L4). Aspects such as questioning, encouraging students to verbalize their thoughts and formulate their own answers were also incorporated into other areas of their teaching (FG6).

> *I'm asking more questions. Even when the students give me an answer I can say now ok but why? I allow them to think more and come up with their own answers instead of jumping in*. (T19.FG6)

T18, T20, T21, T22 and T23 participated in team teaching with the researcher, which they feel helped to improve their questioning skills and their ability to respond to student answers.

> *When a student gave an answer that was not quite right I was able to say 'yes, I see where you're coming from with that but what if we think about it like this? What do you think then? It's shown me better questions to ask to lead them to the right answer* (T18. FG6).

> *Having you there to jump in really helped. I was able to see the point of the lesson and the sorts of questions I should ask*. (T23.FG6)

In general, the teachers collaborated well within their class groups. During focus groups, the teachers organised the sourcing of materials and discussed strategies to implement the lessons successfully. This especially helped T18 who was less confident than the other teachers.

> *I often let the others teach the lessons first so I can ask them about it beforehand. It helps me feel more in control, which allows me to give the students more freedom. I feel I am getting more confident* (T18 L13).

The teachers generally had a positive attitude towards the lessons themselves and felt that they integrated well with the curriculum topics and development of the scientific skills (FG6). Next year, the 4th class students will begin with the set of lessons designed for this year group, which should be more challenging and create more cognitive conflict. However, the second introductory activity "*Make that box*" has been moved from the beginning of the 3rd class programme to the beginning of the 4th class programme as teachers felt that this activity was too challenging for the 3rd class students. Table 6.8 presents the final set of lessons considered suitable for implementation with 3rd and 4th class students.

Table 6.8: Complete set of lessons considered suitable for 3rd and 4th class students

	3rd Class	4th Class
1	Climb that Mountain	Make that Box
2	Who am I?	Where are the forces?
3	All these Bones	Can you change the force?
4	What makes me Move?	Bungee
5	Where do I Live?	Falling
6	How am I Adapted?	Late for School
7	What am I?	Parachutes
8	Who hot are you?	Friction
9	Hotter or Colder?	My bulb won't work
10	I like my Tea Hot (a)	Do I work? (a)
11	I like my Tea Hot (b)	Do I work? (b)
12	Where does it belong?	Controlling the light
13	I can't find the Sugar	
14	Sorting out the mix-ups	

This section has discussed the 3rd and 4th class teachers' implementation of the lessons using the teachers' responses to the written lesson reflections, researcher observations, focus group discussions and responses to Q2. The data for the remaining groups of teachers is analysed in the same manner, as described above, in the following sections. The main points are tabulated where possible to avoid repetition.

6.2 Fifth and Sixth Class teachers

6.2.1 Overview

The 5th and 6th class group consists of seven teachers as shown in Table 6.9. T29 participated in the pilot programme. T28 implemented the lessons, participated in focus group discussions, team-teaching with the researcher and completed Q2, however, the teacher did not complete any lesson reflection sheets. As a result, T28 was not included in the MDS analysis.

Table 6.9: Teachers of 5th and 6th class

5th Class	6th Class
T25	T29
T26	T30
T27	T31
T28	

The 5th and 6th class teachers implemented an adapted version of the *Thinking Science!* programme, as discussed in Chapter 3. Again, the lessons follow a spiral approach and it was not considered suitable to start the 6th class students half way through a programme. Therefore, the 6th class groups completed the first eight activities of the 5th class programme to gain an understanding of the underlying schema involved, and then continued on to the 6th class programme. The teachers in this group also implemented the first two introductory activities, '*Climb that mountain*' and '*Make that box*', from the *Lets Think through Science! 8&9* programme. These lessons were delivered first to allow the students and teachers to become familiar with the CASE methodology and the lesson structure.

Therefore, lessons 1-10 are the same for both class groups. The complete set of lessons implemented by the 5th and 6th class teachers and the lessons received is presented in Tables 6.10 and 6.11 respectively.

Table 6.10: Lessons completed and lesson reflections received for the 5th class teachers (✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		Fifth Class			
		T25	T26	T27	T28
L1	Climb that Mountain	✓	✓	✓	O
L2	Make that Box	✓	✓	✓	O
L3	What Varies	✓	✓	✓	O
L4	Two Variables	✓	✓	✓	O
L5	What sort of relationship? 1	O	✓	✓	O
L6	What sort of relationship? 2	O	O	O	✗
L7	The 'Fair' Test	✓	✓	✓	O
L8	Rollerball 1	✓	✓	✓	O
L9	Rollerball 2	✓	✗	✓	✗
L10	Gears and Ratio	✓	✓	✓	O
L11	Making Groups	O	✓	✓	O
L12	More Classifying	O	✓	✓	✗
L13	Sampling Beans	✗	✗	✗	✗
L14	Bean Growth	✗	✗	✗	✗
Total Lesson Reflections Received		8	10	11	0

Table 6.11: Lessons completed and lesson reflections received for the 6th class teacher (✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		Sixth Class		
		T29	T30	T31
L1	Climb that Mountain	✓	✓	✓
L2	Make that Box	O	✓	✓
L3	What Varies	✓	O	✓
L4	Two Variables	✓	✓	✓
L5	What sort of relationship? 1	✓	✓	✓
L6	What sort of relationship? 2	✗	✗	✗
L7	The 'Fair' Test	✓	O	✓
L8	Rollerball 1	✓	✓	✓
L9	Rollerball 2	✗	✓	✗
L10	Gears and Ratio	✓	✓	✓
L11	Spinning coins 1	✓	✓	✓
L12	Behaviour of Woodlice	✓	✓	✗
L13	Treatments and Effects	✗	✗	✗
L14	Floating and Sinking	✗	✗	✗
Total Lesson Reflections Received		9	9	9

A timeline of the 5th and 6th class groups' implementation of the CASE lessons is presented **in** Figure 6.24. The teachers participated in Focus Groups (FG) 1 and 2 together, however, subsequent focus groups were held separately. After lesson 10, the 5th class teachers continued with the fifth class programme, while the 6th class teachers progressed to the 4th class programme. Therefore, in Figure 6.24, lessons numbered 1 - 10 are the same lessons for all teachers. However, later lessons implemented do not refer to the same lesson for the 5th and 6th class teachers.

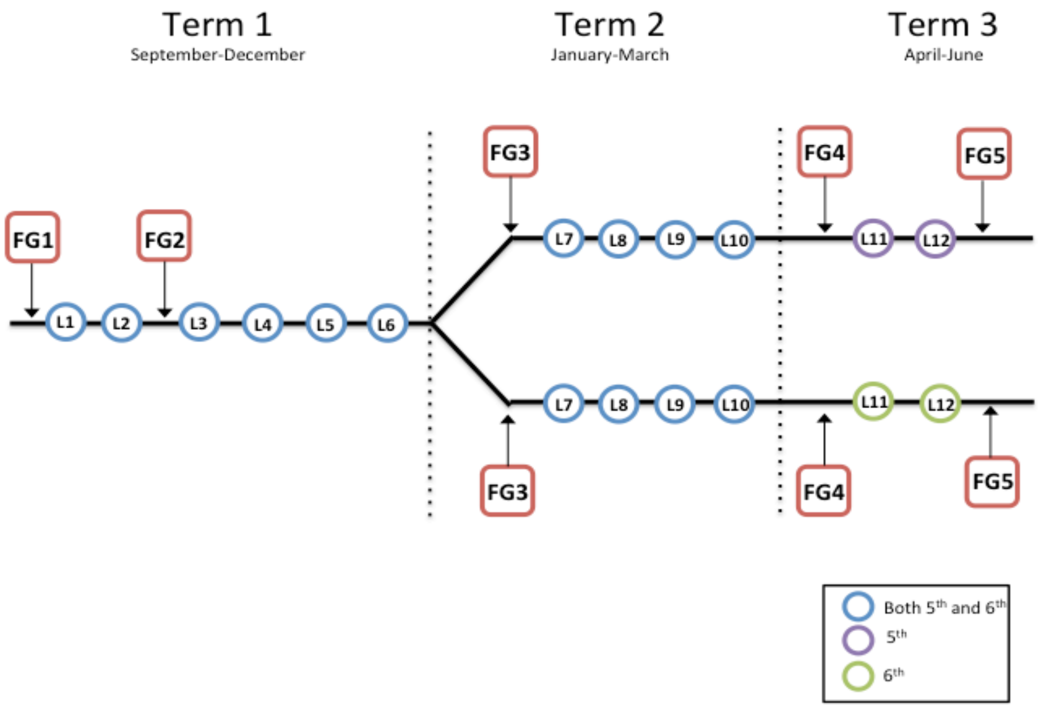

Figure 6.24: Timeline for 5th and 6th class groups' implementation of the CASE lessons

6.2.2 Multidimensional scaling analysis

The data obtained from the 5th and 6th class teachers was analysed with regard to their implementation and confidence, as already described in Section 6.1. Again, the teachers' first three lessons were used as a measure of the their implementation and confidence at the beginning of the programme, and the last three lessons used to give a measure at the end of the programme. The first two introductory activities were not included in the MDS analysis. Figure 6.25, Table 6.12 and Table 6.13 summarise the teachers' change in implementation with regard to the ZAP, and Figure 6.26, Table 6.14 and Table 6.15 summarise the teachers' change in confidence in a similar manner.

a) Implementation

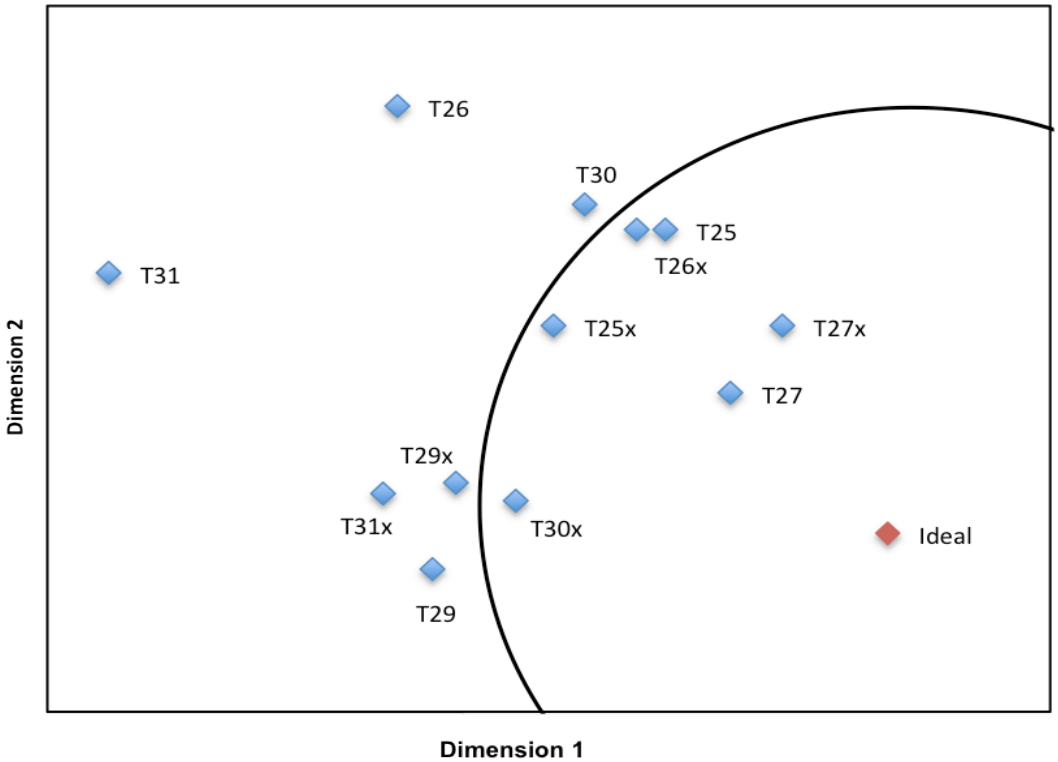

Figure 6.25: 5th and 6th class teachers' change in implementation with regard to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.

Table 6.12: 5th and 6th class teachers' change in implementation from term one to term three with regard to the ZAP

Implementation	
Term 1	**Term 3**
• T25 and T27 are situated within the ZAP • T27 is closest to the ideal • T29 and T30 are just outside the ZAP • T26 and T31 are situated outside the ZAP and furthest from the ZAP	• T25 and T27 move slightly away from the ideal but both remain within the ZAP. • T26 and T30 move closer to the ideal and into the ZAP • T31 moves towards the ideal but is not situated within the ZAP • T29 does not move relative to the ideal and is situated on the outskirts of the ZAP

Table 6.13: Classification of the 5th and 6th class teachers in relation to their implementation of the CASE lessons

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T25, T27
2	Outside ZAP	Inside ZAP	T26, T30
3	Outside ZAP	Outside ZAP	T29, T31
4	Inside ZAP	Outside ZAP	

b) Confidence

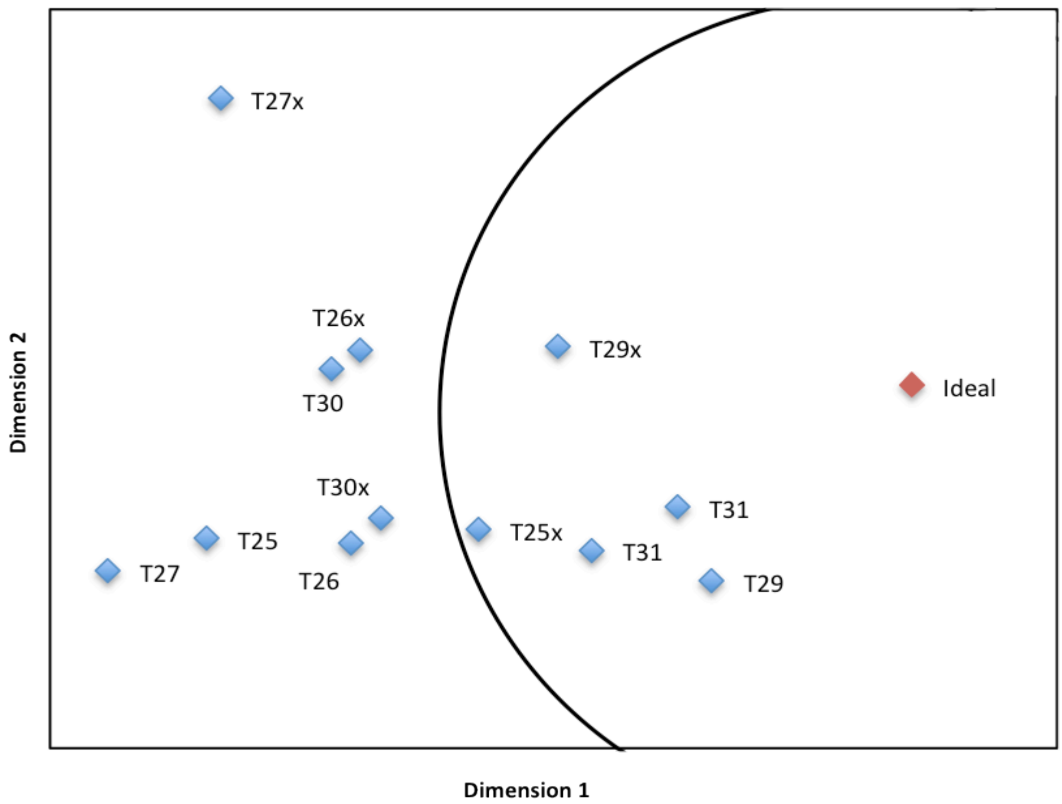

Figure 6.26: 5th and 6th class teachers' change in confidence with regard to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three

Table 6.14: 5th and 6th class teachers' change in confidence from term one to term three with regard to the ZAP

Confidence	
Term 1	**Term 3**
• T29 and T31 are situated closest to the ideal and are within the ZAP • The reaming teachers are all situated distant from ideal • T27 is the furthest from the ideal	• T31 and T29 remain within the ZAP • T25 moves into the ZAP • T26, T27 and T30 do not make any significant movements towards the ideal. T27 remains the furthest from the ideal at the end of term 3.

Table 6.15: Classification of 5th and 6th class teachers in relation to their confidence

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T29, T31
2	Outside ZAP	Inside ZAP	T25
3	Outside ZAP	Outside ZAP	T26 T27 T30
4	Inside ZAP	Outside ZAP	

A matrix was created comparing teachers change in implementation (Table 6.13) with their change in confidence (Table 6.15), which is shown in Figure 6.27. T25, T26, T27 and T30 were successful in their implementation at the end of the programme; however, only T25 was confident. T29 and T31 were largely unsuccessful in in their implementation although both teachers were confident. The teachers' change in implementation and confidence is explored in more within these groups in the next section.

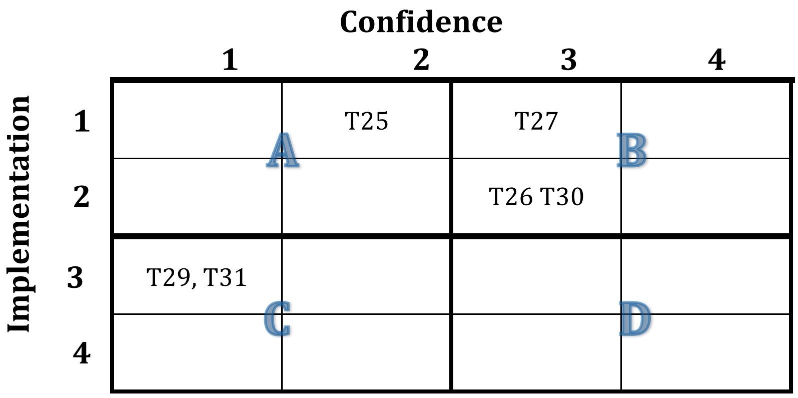

Figure 6.27: **Classification of fifth and sixth class teachers in relation to their implementation and confidence in teaching the CASE lesson.**

6.2.3 Analysis of 5th and 6th Class Teacher Groups

The teachers were classified into four groups based on the MDS analysis of their overall change in confidence and implementation of the CASE lessons. Each individual group will now be discussed as described in Figure 6.27.

Group A

T25's implementation of the lessons is relatively successful throughout the programme, as shown in Figure 6.28. The teacher's confidence varies but increased slightly as the programme progressed. However, T25 only completed 8 out of 12 lesson reflections. Of the four lesson reflections not completed, one was at the beginning of the programme and two were the last two lessons implemented by the teacher. Therefore the lessons used to measure T25's implementation and confidence at the beginning and end of the programme were the middle lessons implemented, and may explain why T25 showed no significant change in implementation or confidence.

T25 was successful in their implementation of the pillars of concrete preparation and cognitive conflict from the beginning of the programme, and the teacher was relatively confident as shown in Figure 6.29. However, T25's implementation of the pillar of metacognition decreased from term one to term three and was largely unsuccessful throughout the programme.

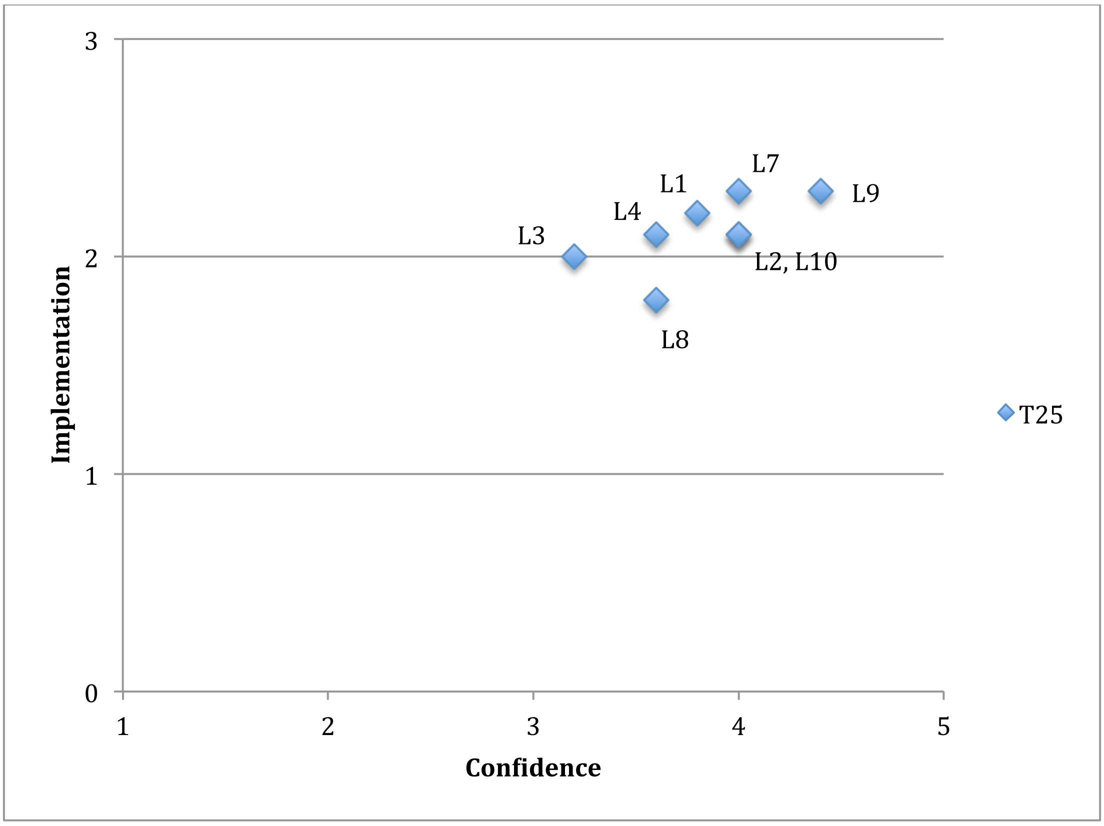

Figure 6.28: 5th and 6th class teachers' (Group A) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.10 and Table 6.11.

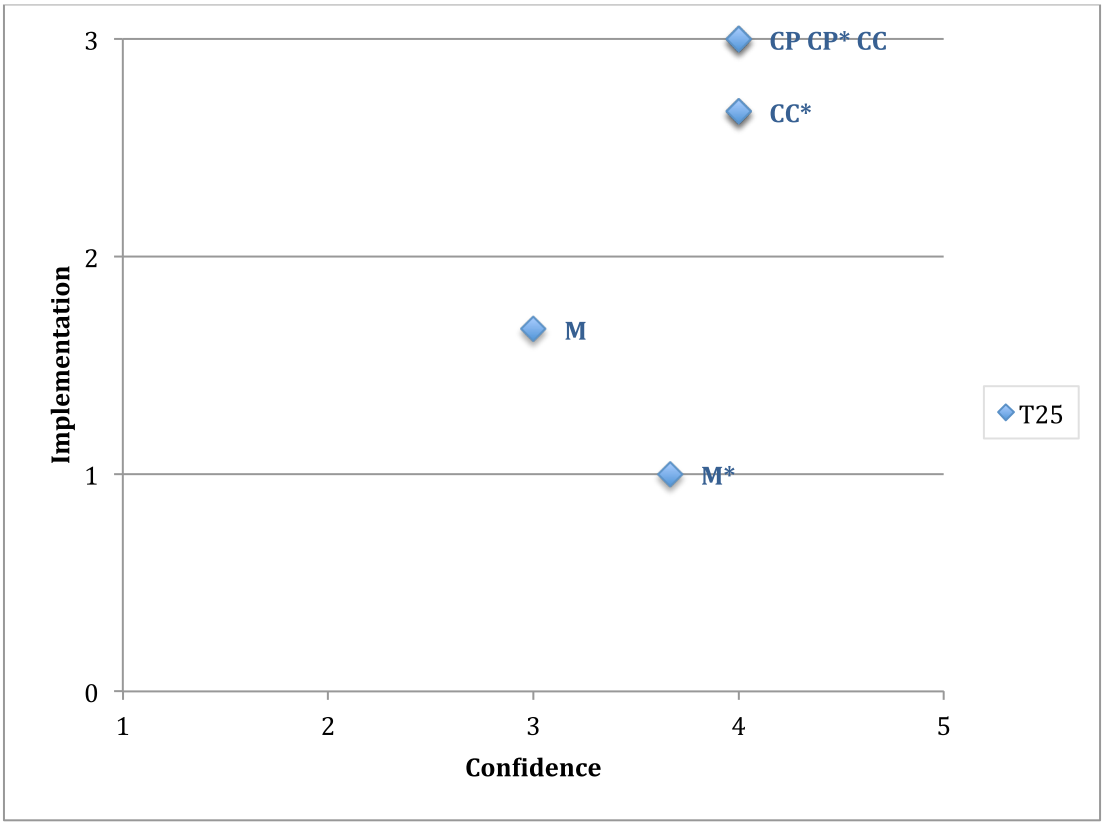

Figure 6.29: 5th and 6th class teachers' (Group A) implementation versus confidence for each pillar. Notation described in Table 6.7.

Group B

In general, teachers in Group B were successful in their implementation of the lessons at the end of the programme, however they were not considered confident. The progress of three 5th and 6th class teachers in Group B varies slightly, as shown in Figure 6.30. T26's implementation of the lessons improved as the programme progressed; however, she was not consistent in her implementation and L9, which was implemented towards the end of the programme, was not successful. T27 was consistently successful in her implementation of the lessons. However, the teacher's confidence varies for each lesson, and there was no overall improvement in this as the programme progressed. T30 shows very little change in relation to their confidence or implementation of the lessons. Towards the end of term three, the teacher's implementation of the lessons was largely successful however, he was not very confident in his implementation.

At the end of term three, all three teachers were successful in their implementation of the pillars of concrete preparation and cognitive conflict, however none of the teachers were very confident, as shown in Figure 6.31. Towards the end of the programme, T27 is confident in her implementation of the pillar of concrete preparation. Only T27 is successful in her implementation of the pillar of metacognition at the end of the programme. However, T27 could improve further in relation to her confidence and implementation of this aspect. T26 and T30 were unsuccessful in their implementation of this from the beginning of the programme and neither teacher made any improvements as the programme progressed.

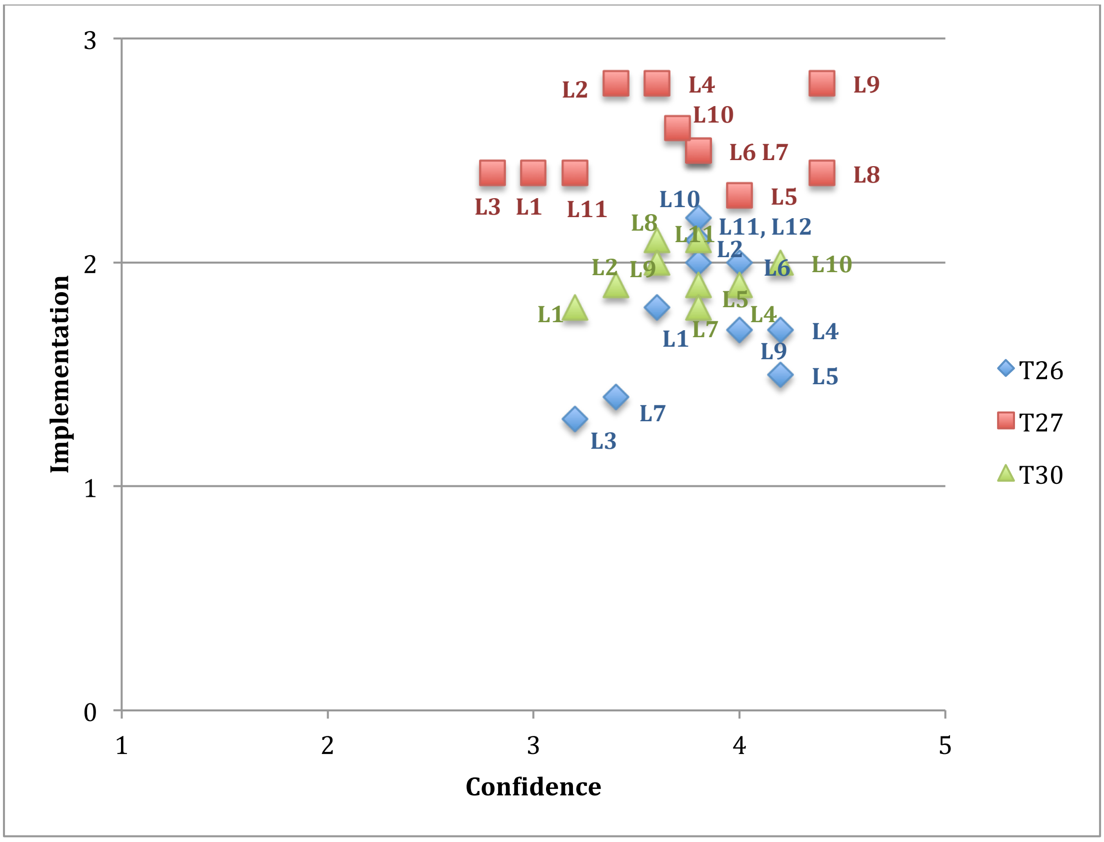

Figure 6.30: 5th and 6th class teachers' (Group B) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.10 and Table 6.11.

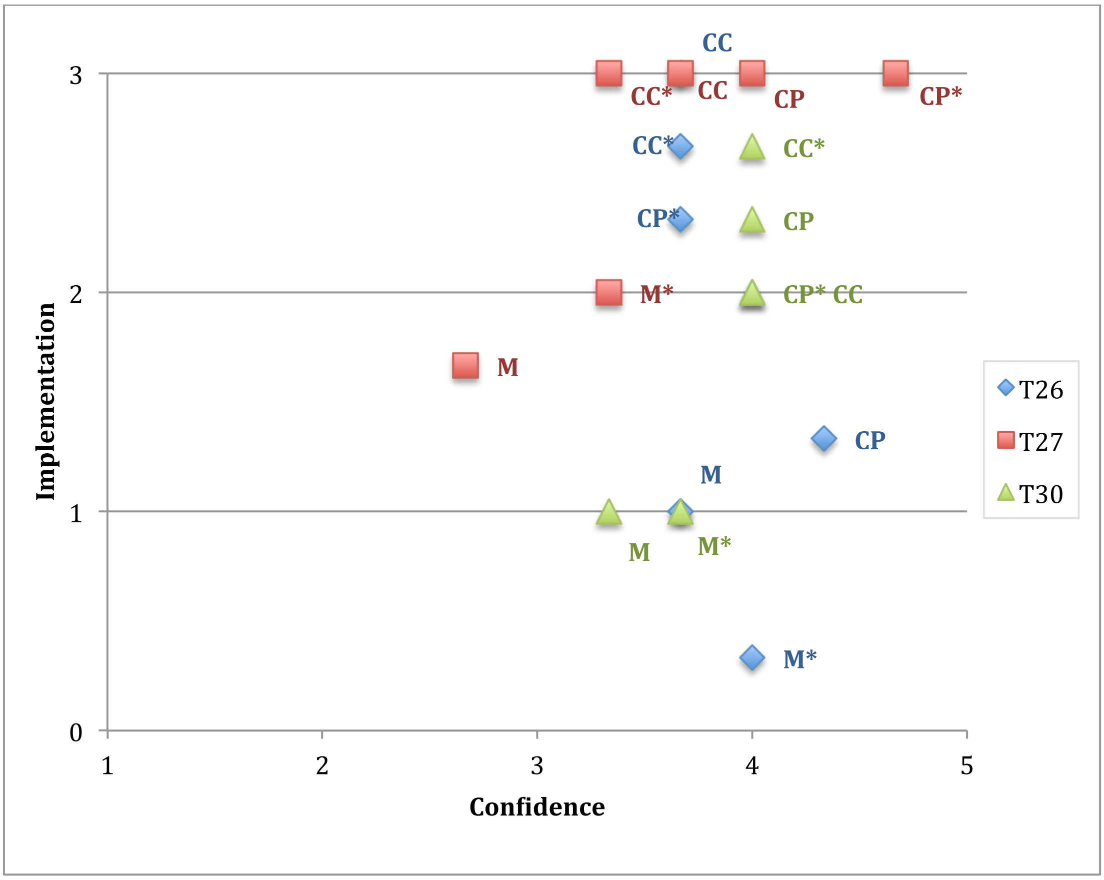

Figure 6.31: 5th and 6th class teachers' (Group B) implementation versus confidence for each pillar. Notation described in Table 6.7.

Group C

T29 and T31 were largely unsuccessful in their implementation of the lessons at the end of the programme, however this was not reflected in their confidence, as shown in Figure 6.32. T29 was consistently confident in her implementation of the lessons however, only one lesson, L10, was implemented successfully by the teacher. Three lessons (L2, L7, L12) were implemented successfully by T31, however the teacher was inconsistent in her implementation, and the majority of lessons remained unsuccessful at the end of the third term. Despite this, T29 and T31 were generally confident in their implementation of the CASE lessons.

T29 and T30 were also over confident in their ability to implementation each of the pillars of the CASE lessons, as shown in Figure 6.33. At the end of the programme, both teachers were reasonably successful in their implementation of the concrete preparation phase of the lesson, although T29 and T31 could improve further. While both teachers improved slightly in their implementation of the pillar of cognitive conflict, they remained unsuccessful at the end of the programme. T31 displays a small improvement in her implementation of the pillar of metacognition, however this remained largely unsuccessful at the end of term three. T29 was reasonably successful in her implementation of the pillar of metacognition at the beginning of the programme, however this deteriorates towards the end of term three. T31 improved slightly in their implementation of this pillar, but remained largely unsuccessful at the end of term three. It should be noted that, towards the end of the study, T31 did not complete all aspects of the lesson reflections, which may distort her results. In order to analyse whether the 5th and 6th class teachers' responses to the lesson reflections were an accurate assessment of how successful the lesson implementation was they were compared with the researchers observations, which is discussed in the next section.

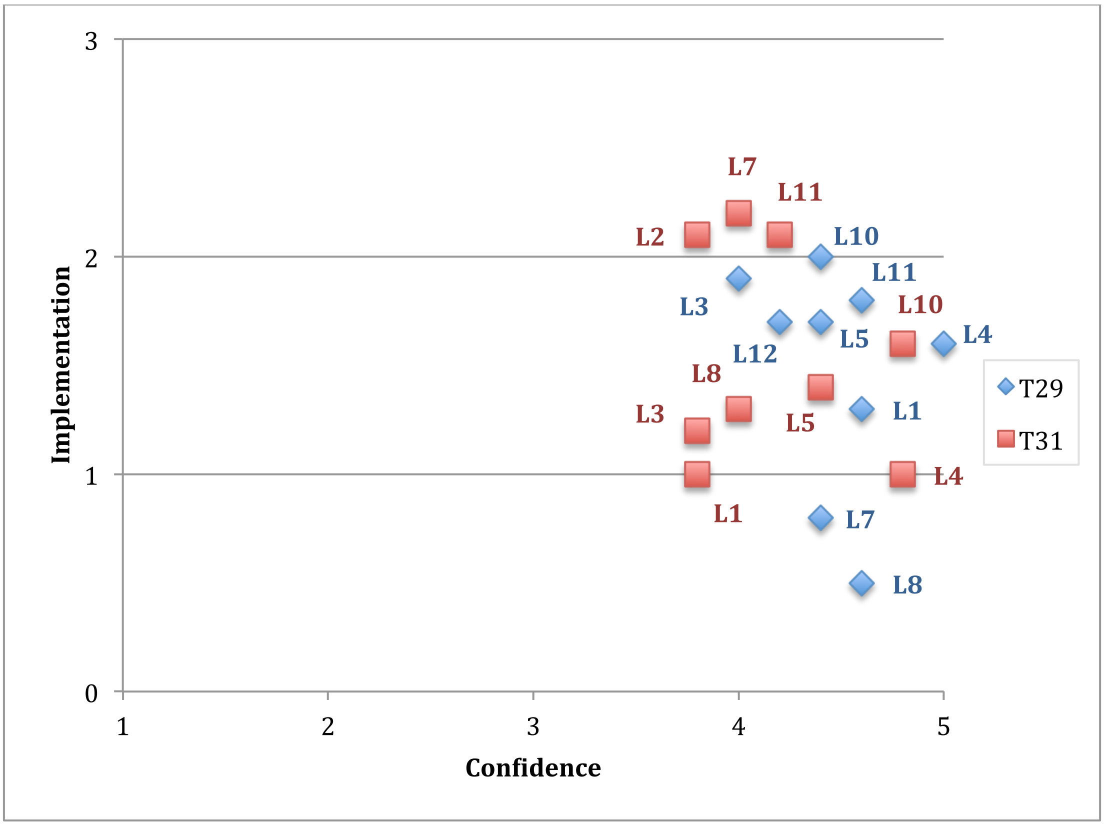

Figure 6.32: 5th and 6th class teachers' (Group C) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.10 and Table 6.11.

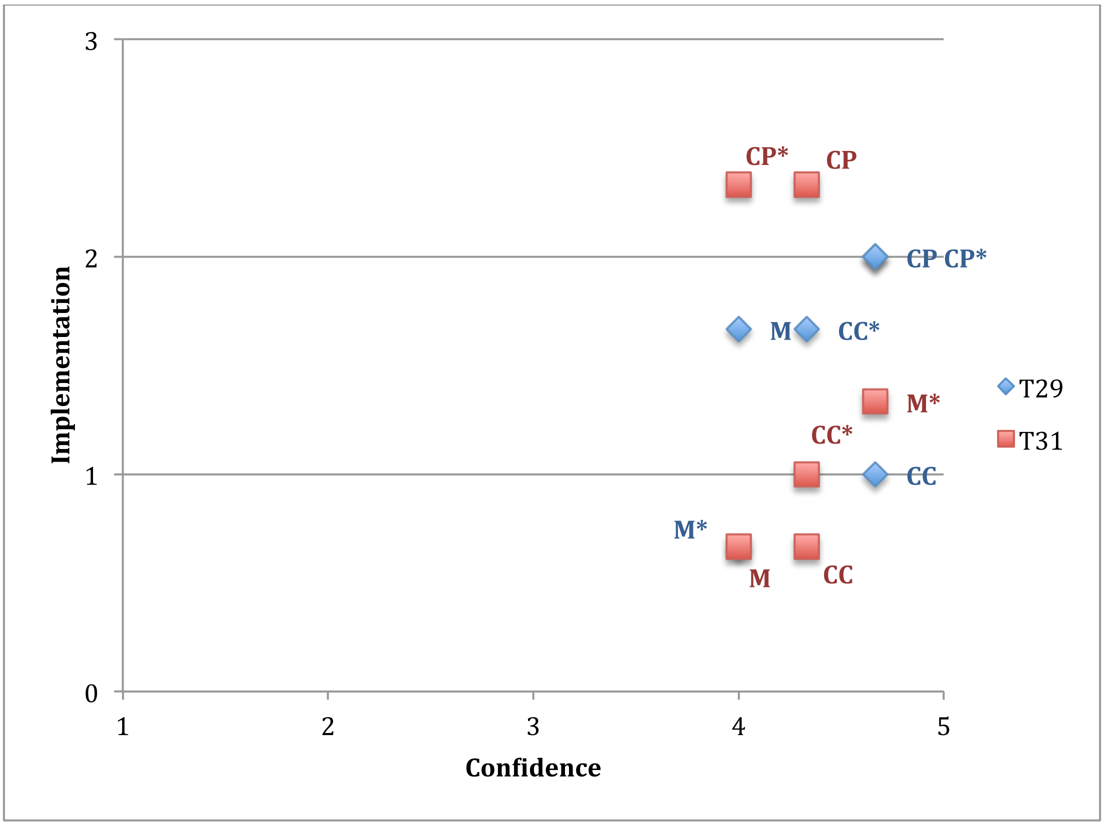

Figure 6.33: 5th and 6th class teachers' (Group C) implementation versus confidence for each pillar. Notation described in Table 6.7.

6.2.4 Researcher observations for the 5th and 6th class teachers

Again, the researcher's observations were compared with the teachers' responses to the lesson reflections, as shown in Figures 6.34 and 6.35. The 5th and 6th class teachers were observed between 5 and 7 times. T25 did not participate in observations during the programme and is therefore not featured in this analysis. The researcher's observations for T27 generally agree with the teacher's responses to the lesson reflections, as shown in Figure 6.34. Both the teachers' responses to the lesson reflections and the researcher observations indicate that the T27's implementation of the lessons was successful. However, researcher observations for T26 do not completely agree with the teachers' responses to the lesson reflections. Figure 6.34 highlights that four lessons (L8, L10 and L12) were considered reasonably successful by the researcher, however the teacher's responses to the lesson reflections suggest that they were unsuccessful.

If the researcher's observation rating is substituted in place of the teacher's rating from their responses to the lesson reflection, as described in Section 6.1.7, the point can be shifted, as shown in Figure 6.35. This movement of lessons suggests that T26's implementation of the lessons was more successful than suggested by her responses to the lesson reflections. At the end of the programme, T26 was situated just inside the ZAP in relation to her implementation and the teacher is in Group B. Although researcher observations indicate that T26 should be situated closer to the ideal, this movement would keep the teacher within Group B in Figure 6.27

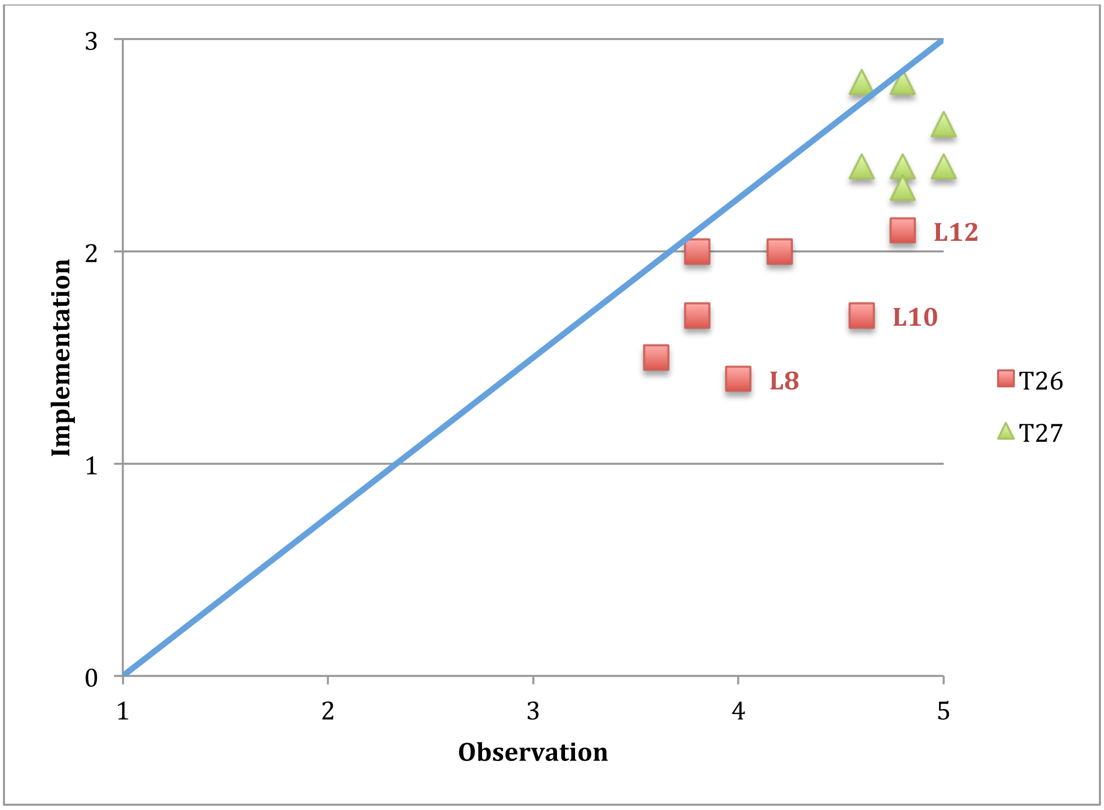

Figure 6.34: Researcher observations versus lesson implementation rating generated from the 5th class teachers' responses to the lesson reflections

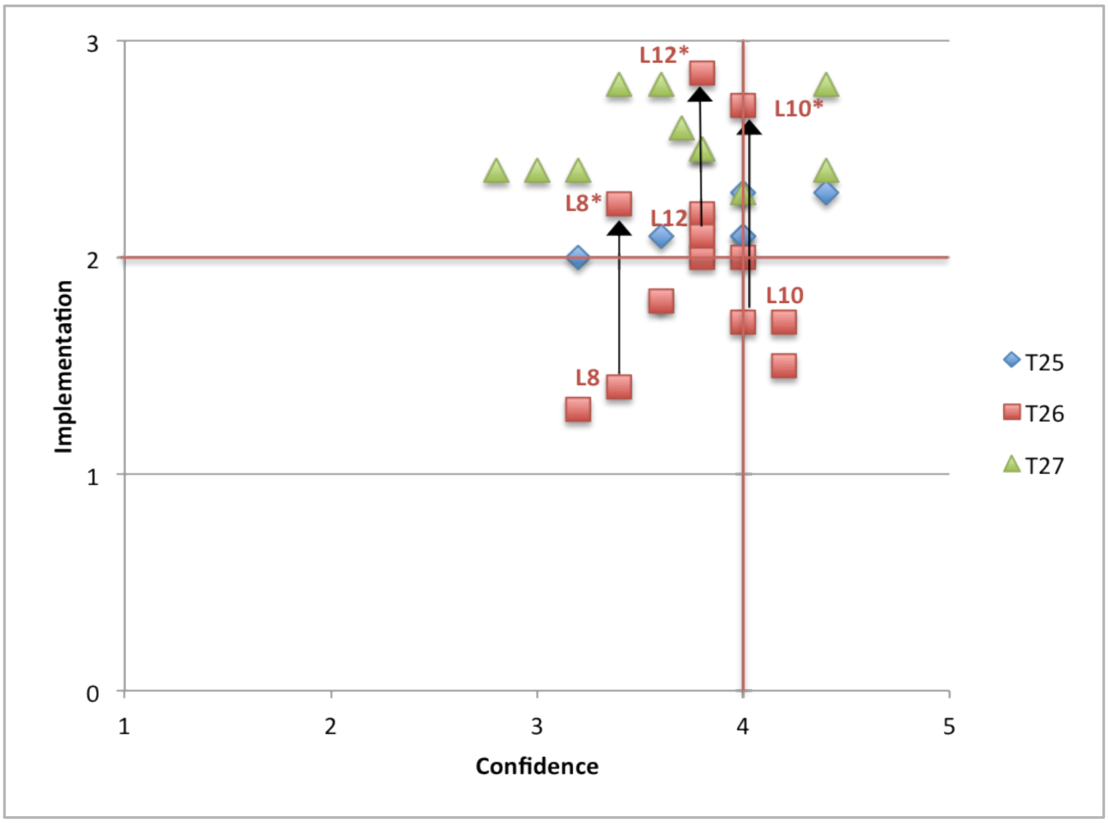

Figure 6.35: 5th class teachers' implementation of the CASE lessons using the researcher's observation rating in place of the rating generated from the lesson reflections. The asterisk (*) beside the lesson code signifies the implementation using the researcher's observation.

The 6th class teachers' implementation ratings obtained from the lesson reflections were also compared with the researcher's observations ratings, as shown in Figure 6.36. T30 was observed on four occasions, each of which generally agree with the researcher's observations. For T29, both the teacher's responses to the lesson reflections and the researchers observations indicate that the teacher's implementation of the lessons was unsuccessful throughout the programme. However two lessons (L3, L8) for T29 do not completely agree with the researcher's observations. T29's marker for L3 is obscured, however the lesson position is highlight using the shorthand 'L3'. If the researcher's observation rating is substituted in place of the rating generated from the lesson reflections, the points can be shifted accordingly, as shown in Figure 6.37. This movement does not lead to any significant change in the teacher's implementation of the lessons, which remained largely unsuccessful throughout the programme. Researcher observations for T31 indicate that the teacher's implementation of lessons L8 and L10 was more successful than suggested by the teacher's responses to the lesson reflection, as shown in Figure 6.36. Figure 6.37 highlights that, if these points are shifted, the teacher was successful in her implementation of L7 and L10. As previously mentioned, T31 left sections of the lesson reflections blank towards the end of the programme and, as a result, the teachers' responses to the lesson reflections may not be an accurate reflection of how successful the teacher's implementation was.

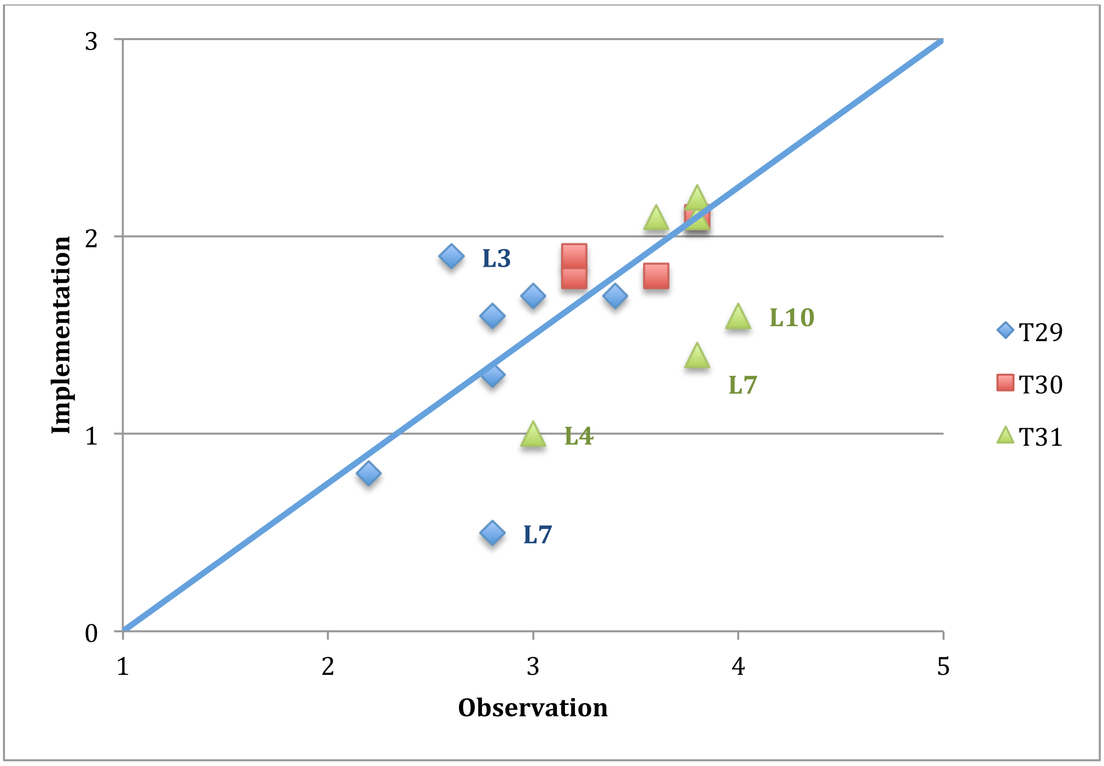

Figure 6.36: Researcher observations versus lesson implementation rating generated from the 6th class teachers' responses to the lesson reflections

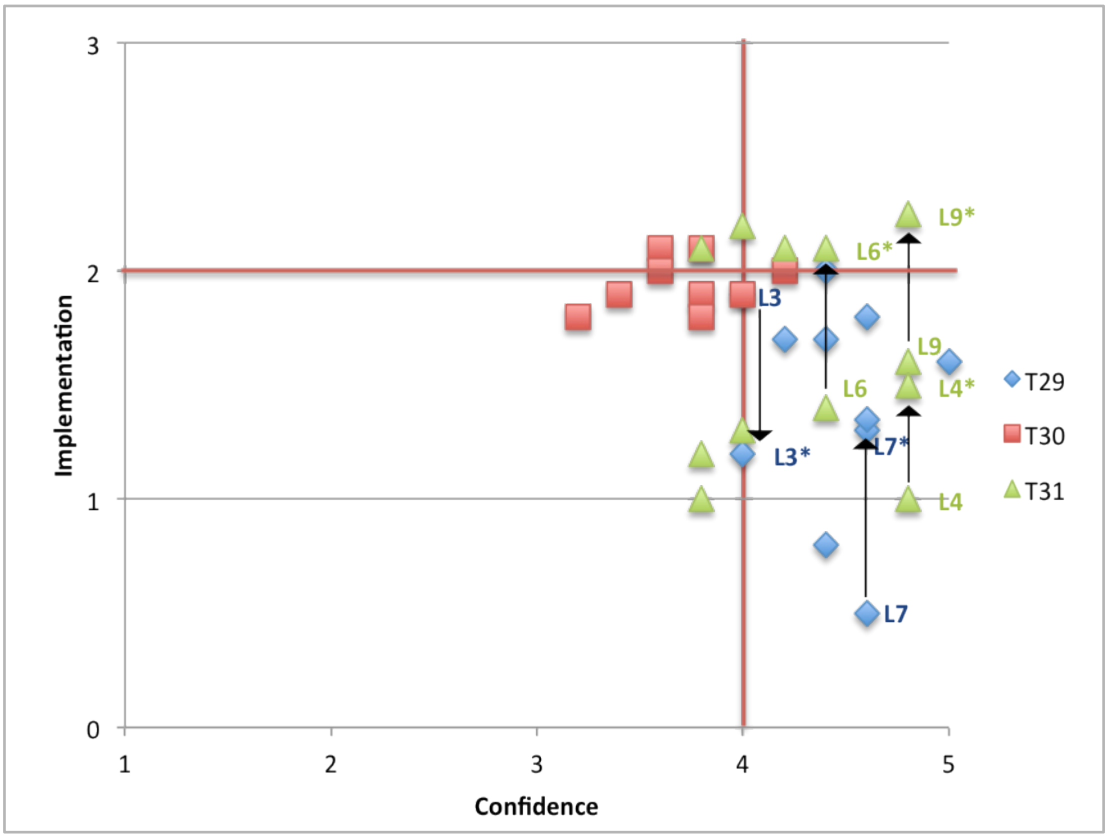

Figure 6.37: 6th class teachers' implementation of the CASE lessons using the researcher's observation rating in place of the rating generated from the lesson reflections. The asterisk (*) beside the lesson code signifies the implementation using the researcher's observation.

6.2.5. 5th and 6th class teachers' confidence in their understanding of the science content in the CASE lessons

The teachers' confidence in their understanding of the science content was compared against their implementation of the lessons, as shown in Figures 6.38 and 6.39. As previously mentioned, L1 – L10 are the same for the 5th and 6th class teachers. The 5th class teachers' confidence in their understanding of the science content in the CASE lessons varied, as shown in Figure 6.38. T25 was consistently confident in his understanding of the science content and was generally successful in his implementation.

T26's confidence in her understanding of the science content varied. The teacher was not very confident in her scientific understating of lessons L2, L3, L4, L7, L8, L10 and she was largely unsuccessful in her implementation of these lessons. However, as mentioned in the previous section, researcher observations for T26 indicate that the teacher's implementation of the lessons was generally more successful than suggested by her responses to the lesson reflections, and that the teacher was actually successful in her implementation of L8 and L10, as shown in Figure 6.35. This indicates that, although T26 is not very confident in her understanding of the scientific content in the lessons, she was often successful in her implementation.

T27's confidence in her understanding of the science content also varied, as shown in Figure 6.38. Despite this, T26 was consistently successful in her implementation of the lessons. There appeared to be no lesson, or group of lessons, that all of the 5th class teachers lacked confidence in their understanding of the science content, although T26 and T27 were less confident in their scientific knowledge regarding L8 and L10.

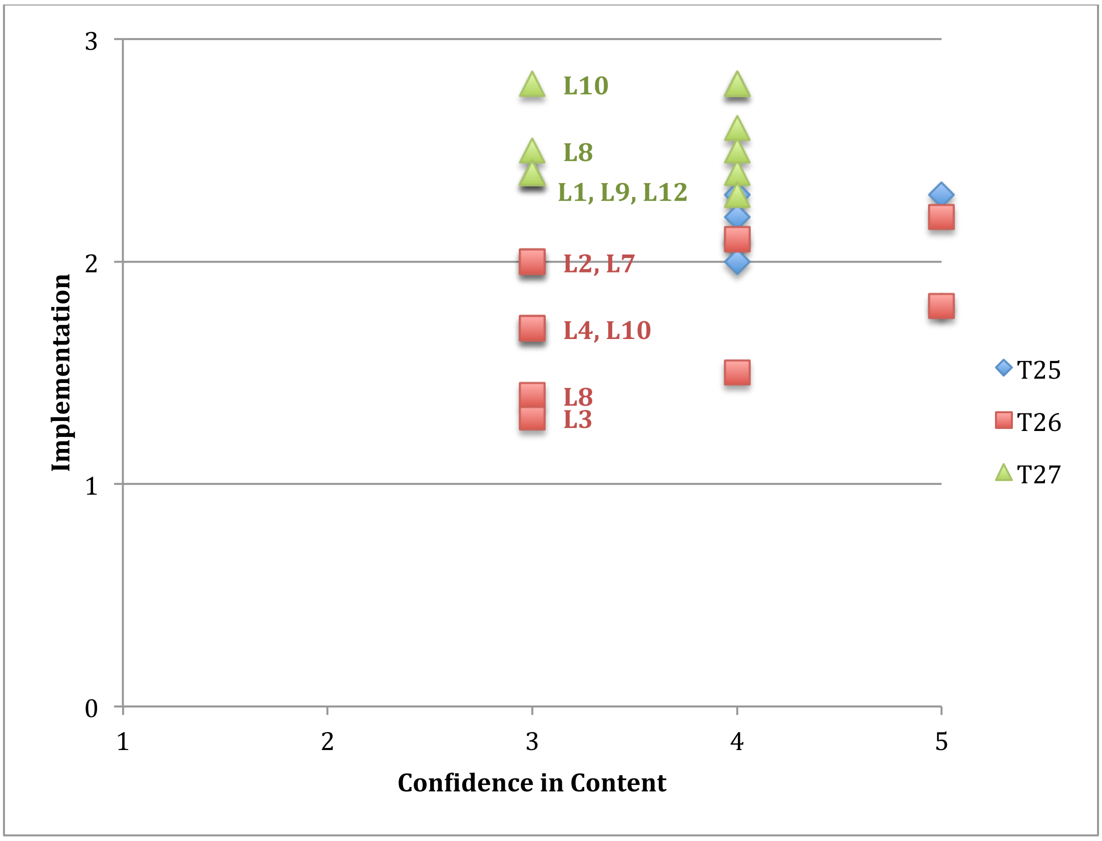

Figure 6.38: 5th class teachers confidence in their understanding of the science content covered in the lessons versus their implementation

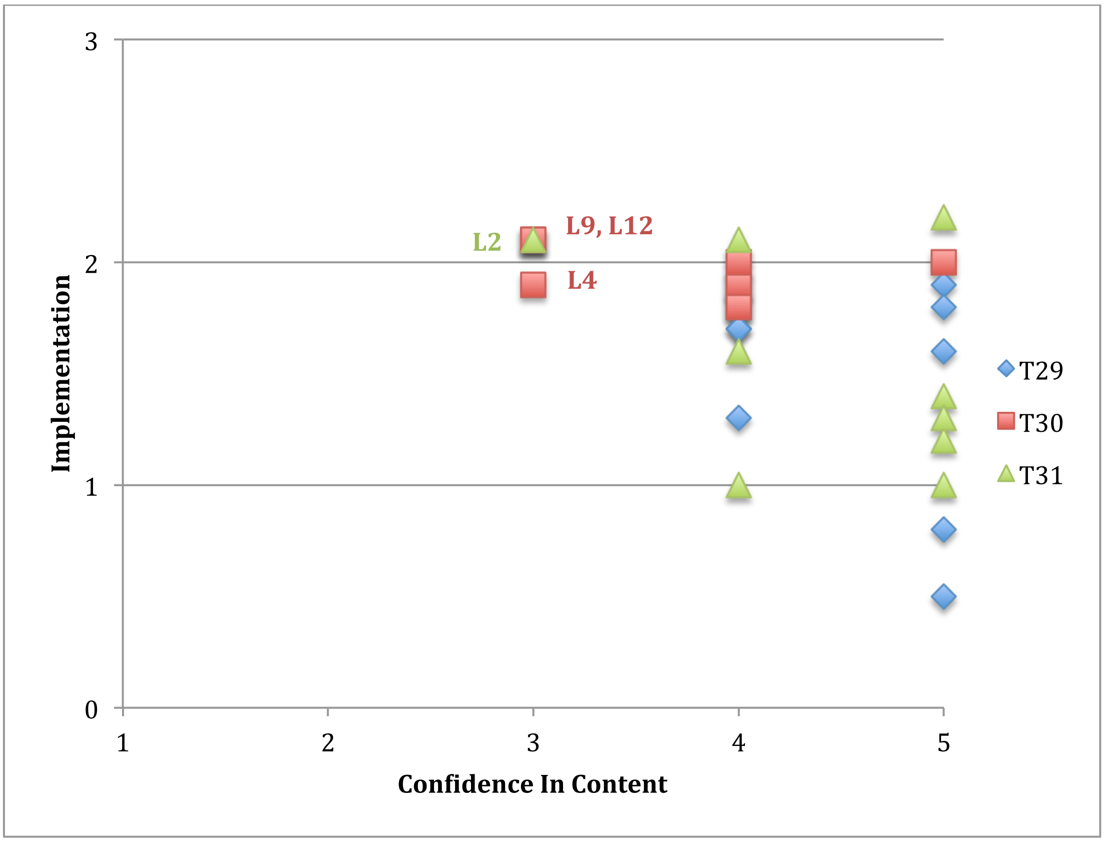

Figure 6.39: 6th class teachers confidence in their understanding of the science content covered in the lessons versus their implementation

In general, the 6th class teachers were more confident in their understanding of the science content in the lessons than the 5th class teachers, however they were less successful in their implementation, as shown in Figure 6.39. T30's confidence varied, however this did not appear to have an effect on his implementation, which remained roughly constant throughout the programme. T29 was consistently confident in her understanding of the science content, however the teacher was also consistently unsuccessful in her implementation, as shown in Figure 6.39.

T31 was also generally confident in her understanding of the science content in the CASE lessons. The teacher was not very confident in her understanding of the science content in introductory activity L2 (*Make that box*), which suggests that the teacher was not very confident in her understanding of the methodology, rather than any science content. T31's confidence in her understanding of the science content covered in the lessons does not appear to have an effect on her implementation of the lessons, which is generally unsuccessful. However, as previously discussed in Section 6.2.4, researcher observations for T31 suggest that her implementation of the lessons was more successful than suggested by her responses to the lesson reflections.

Again, this analysis suggests that there is no overall effect of the teachers' confidence in their understanding of the science content on their implementation of the lessons. The teachers' confidence in their understanding of the science content regarding each lesson is specific to the individual, as shown in Figures 6.38 and 6.39. The teachers' confidence in their understanding of the science content agrees with the classification of the teachers in Figure 6.27. T25 is in Group A indicating that he is confident and successful in his implementation while T26, T27 and T30 are in Group B indicating that the teachers were also successful in their implementation of the lessons, although they are less confident in their implementation. These three teachers are also not very confident in their understanding of the science content in the lessons. T29 and T31, who are generally confident in their understanding of the science content covered in the lessons, are in Group C in Figure 6.27, indicating that they are also confident in their ability to implement the lessons despite being largely unsuccessful.

Although the 5th class teachers' confidence in their understanding of the science content does not appear to have hindered their implementation of the lessons, the teachers could improve in relation to their confidence. The *Thinking Science!* lessons implemented by the teachers in this group were originally developed for use in second-level with subject specific science teachers, and may explain why the 5th class teachers were not very confident in their understanding of the science content. On the other hand, the 6th class teachers were confident in their understanding of the science content but were less successful in their implementation of the lessons. During observations, the researcher noted that the 6th class teachers' often lacked the science content knowledge required to implement the lessons successfully, which impeded the flow of the lesson. To improve their confidence and implementation of the lessons, both the 5th and 6th class teachers should be provided with more opportunities to engage with the CASE lessons and become familiar with the science content.

6.2.6. The 5th and 6th class teachers and the CASE methodology overall

This section provides an overview of the 5th and 6th class teachers' engagement with the CASE methodology. Data sources include the teachers' responses to lesson reflections Q2, focus group discussions and researcher observations. T25 and T27 participated in focus group discussions, however the teachers did not respond to Q2.

In general, the 5th and 6th class teachers improved in their ability to implement the CASE lessons from the beginning of the programme. The teachers' implementation of the pillars of concrete preparation and cognitive conflict were largely successful at the end of term three. Again, the pillar that teachers had most difficulty in implementing was the pillar of metacognition. The teachers did not make any improvements in the implementation of this pillar by the end of the programme.

The 5th and 6th class teachers' responses to Q2 indicate that they had positive attitudes towards the CASE methodology. The teachers considered the CASE lessons to have an increased focus on students' thinking, which is not something they always do in their teaching (Q2).

> (CASE) *focuses on facilitating the thinking skills needed for science whereas I think I tend to focus more on scientific content* (T31.Q2)

The teachers felt that the lessons integrated well with the primary science curriculum, in that they encouraged students to develop their scientific skills and assisted students in constructing their own understanding (FG5). Lessons such as '*Sampling Beans', 'Gears and Ratio'* and '*Spinning Coins' also* overlap with the maths curriculum and could be used to develop students' understanding of chance and proportional reasoning (FG5). T30 felt that the lessons helped his students to transfer their thinking to other areas of learning:

> *It's a very valuable methodology –especially in how it 'transfers' modes of thinking to other subjects – namely geography and maths but surprisingly, history* (T30.Q2)

The original *Thinking Science!* lessons were designed for use with students between the ages of 11 and 14 years. The lessons have previously been implemented with 6th class students in Irish primary schools (aged between 11 and 12 years), and shown to have positive effects on their cognitive development (McCormack, 2009). In this study, adapted versions of the lessons were also implemented with 5th class students, who are typically aged between 10 and 11 years. As discussed in Chapter 3, a number of lessons were divided into two, and the language simplified, for use with students at this level. The teachers felt that the lessons were suitably challenging for their students, although some students needed more guidance than others (FG5). At times, the teacher slowed the pace of the lessons to ensure that all of the students engaged with the task. Figure 6.35 and Figure 6.37 indicate that the 5th class teachers were generally more successful in their implementation of the lessons than the 6th class teachers, despite their students being a year younger. This supports the idea that the teachers' implementation of the lessons is very much dependent on the individual teacher, rather than on the lessons or the class level taught.

The teachers struggled with their implementation of the lessons at the beginning of the programme, as they attempted to shift from leading the class to facilitating class discussions (FG3). Sharing the control of the learning process with the students was a particular problem for T30 and T31.

> *I know this is the way we're supposed to be teaching and it's great for the students to have a chance to give their own opinion. They love that. But I find it hard sometimes to manage the class (*T31.FG3*).*

The teachers' became more familiar with the methodology as the programme progressed, and they were more confident in allowing their students to investigate and become autonomous in their learning (FG5).

The teachers were slightly overwhelmed by the amount of information in the lessons, particularly at the beginning of the programme.

> *It's hard to remember what's coming next because there is so much in the lessons. (T30. FG3)*

It was suggested to all teachers in Focus Group 3 that they make some brief points on a sheet prior to implementing the lessons to help them remember the procedure of the lesson. This particularly helped T28, who was not confident in her ability to implement the lessons. In Q2, all of the teachers responded that the lessons would be easier to implement next, as they will be more familiar with the methodology and lesson structure. All of the teachers, excluding T25, participated in team teaching with the researcher, which they found beneficial (FG5), This particularly helped T28 who was not very confident in her ability to guide her students through the cognitive conflict.

> *It was great to have you there and see how you did it with one group and then I went to the next group and did the same. It really helped. (T28.L4).*

The discussion in Section 6.2.5 indicated that the 5^{th} and 6^{th} class teachers' confidence in their understanding of the scientific content in the lessons was not a factor in the teachers' success in their implementation. This generally agrees with the researcher's observations, as the majority of teachers were successful in guiding their students through the pillars of the CASE lessons. However, at times, the teachers' lack of scientific content knowledge became apparent during the lessons, although this did not have any significant effect on the teachers' implementation. In their responses to Q2, all of the 5th and 6th class teachers felt that their scientific content knowledge had improved through teaching the CASE lessons, although the teachers felt that they needed to improve their science knowledge further. Developing the teachers' knowledge of the schemata involved and science content in the lessons may increase the teachers' confidence and assist them in their implementation.

T29, who participated in the pilot study, was very confident in her understanding of the CASE methodology and in her ability guide her students through the pillars of the lessons (Q2). She felt that having two years experience with the methodology allowed her to be more prepared and familiar with the lessons. However, although the teacher's implementation of the lessons during the whole-school phase was slightly more successful than during the pilot programme, the teacher tended to reveal the outcome of the lesson to her students and often did not ask the students any questions to challenge their thinking. This suggests that the T29 needs further support in implementing the lessons.

Overall, the 5th and 6th class teachers improved in their ability to guide their students through the cognitive challenge in the lessons and were better ale to facilitate class discussions. The teachers felt that their confidence and understanding of the methodology improved as the programme progressed, and that they will more confident in their implementation next year. While the teachers' content knowledge did not appear to have had a significant effect on the their implementation of the lessons, the teachers could be further supported to develop their understanding of the schema involved with the CASE lessons. The teachers were also unable to engage their students in metacognitive discussions. This is discussed in more detail in Chapter 7.

6.3 Second Class Teachers

6.3.1 Overview

The 2nd class group consists of four teachers, none of whom participated in the pilot study. T16 took part in focus groups and implemented a number of lessons but did not complete Q1, Q2 or any of the lesson reflections. As a result, T16 was not considered as part of this analysis.

Table 6.16: Teachers of second class

2nd Class
T13
T14
T15
T16

The lessons completed by each teacher and the lesson reflections received is presented in Table 6.17.

Table 6.17: Lessons completed and lesson reflections received for the 2nd class teachers (✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		Second Class			
		T13	**T14**	**T15**	**T16**
L1	Money matters	✓	✓	✓	O
L2	Painted doors	✓	✓	✓	O
L3	Grouping foods	✓	✓	✓	O
L4	Animals and teeth	✓	✓	✓	O
L5	Sandwiches	✓	✓	✓	O
L6	Are they seeds?	✓	✓	✓	✗
L7	Clothes to wear	✓	✓	✓	O
L8	Classifying materials	O	✓	✓	O
L9	Classification of Rocks	✓	✗	✗	✗
L10	Composition of Soils	✗	✗	✗	✗
L11	Sorting magnetic materials	✗	✗	✗	✗
L12	Strength of magnets	✗	✗	✗	✗
Total Lesson Reflections Received		8	8	8	0

A timeline of the 2nd class group's implementation of the CASE lessons is presented in Figure 6.40.

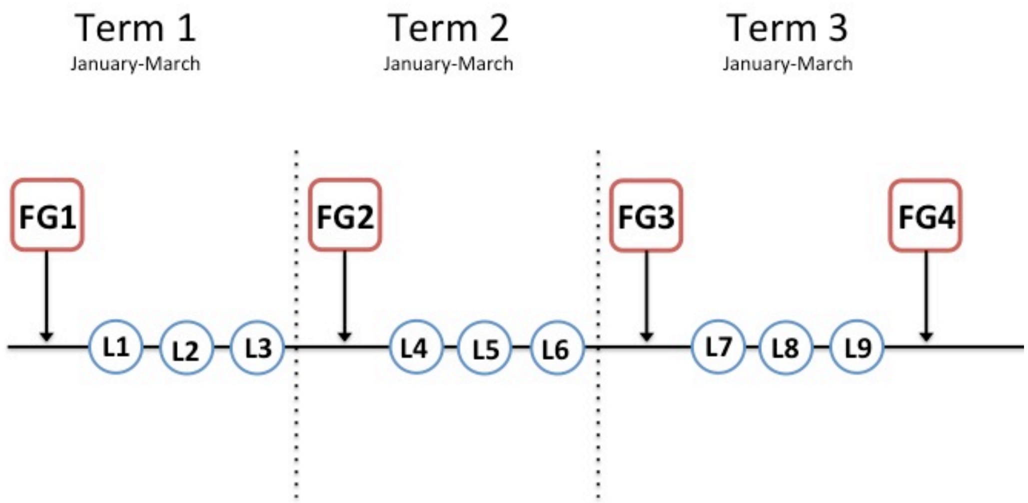

Figure 6.40: Timeline for the 2nd class groups' implementation of the CASE lessons

6.3.2 Multidimensional scaling

The data obtained from the 2nd class teachers was analysed with regard to their implementation and confidence, as already described in the previous sections of this chapter. Again, the first two introductory activities "*Money Matters*" and "*Painted Doors*" were not included in the MDS analysis. Figure 6.41, Table 6.18 and Table 6.19 summarise the teachers' change in implementation with regard to the ZAP, and Figure 6.42, Table 6.20 and Table 6.21 summarise the teachers' change in confidence in a similar manner.

a) Implementation

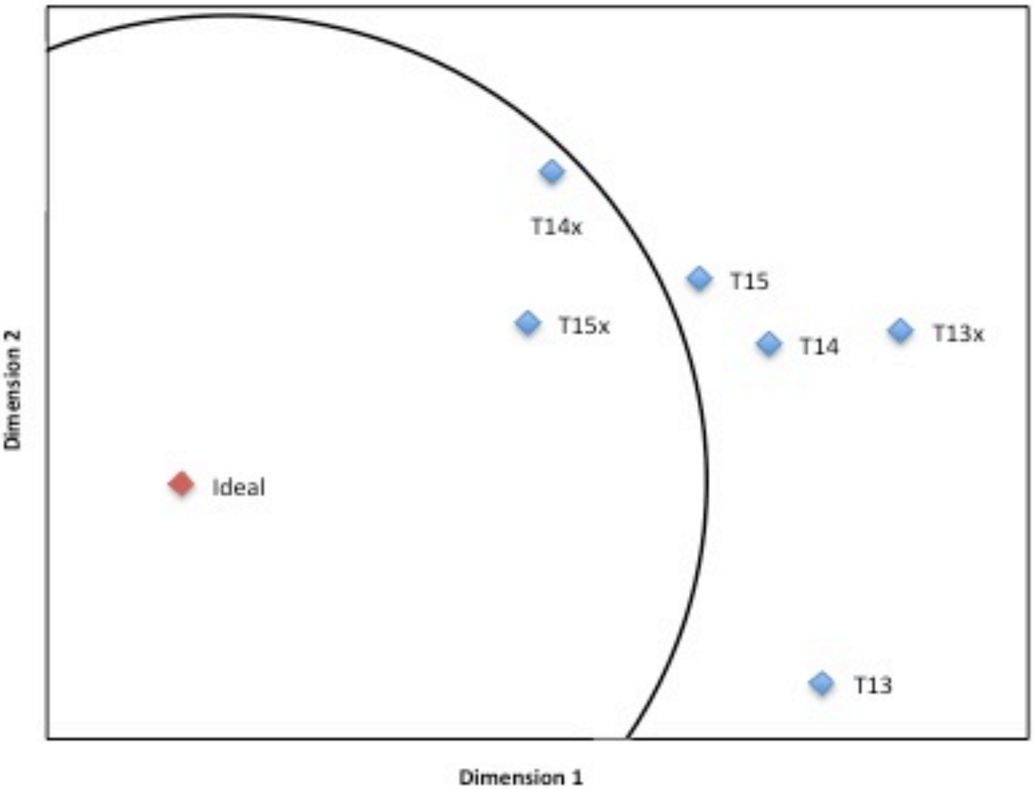

Figure 6.41: 2nd teachers' change in implementation relative to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.

Table 6.18: Second class teachers' change in implementation from term one to term three

Implementation	
Term 1	**Term 3**
• All three teachers were situated just outside the ZAP, indicating that their implementation of the lessons was largely unsuccessful	• T13 makes no significant movement towards the ideal and remains outside the ZAP • T14 and T15 move towards the ideal and into the ZAP.

Table 6.19: Classification of the 2nd class teachers in relation to their implementation

	Term 1	**Term 3**	**Teachers**
1	Inside ZAP	Inside ZAP	
2	Outside ZAP	Inside ZAP	T14, T15
3	Outside ZAP	Outside ZAP	T13
4	Inside ZAP	Outside ZAP	

b) Confidence

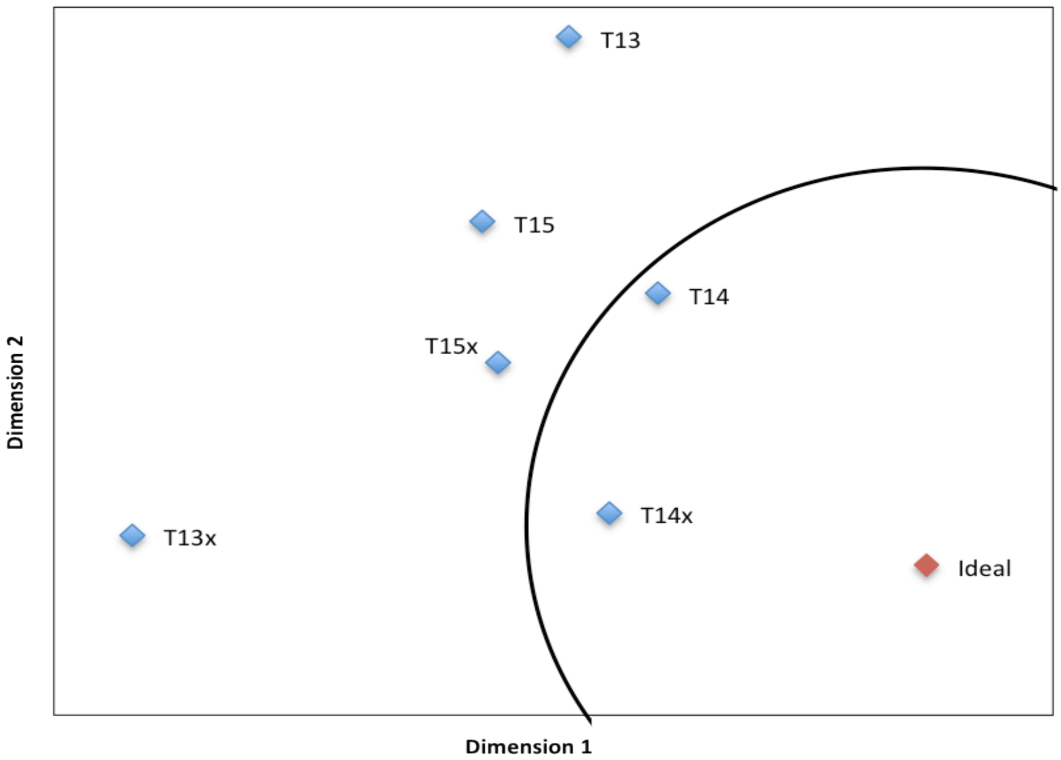

Figure 6.42: 2nd class teachers' change in confidence relative to the ZAP from term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.

Table 6.20: Second class teachers' change in confidence from term one to term three

Confidence	
Term 1	**Term 3**
• T14 is situated within the ZAP • T13 and T15 are situated outside the ZAP	• T14 moves slightly closer to ideal and remains within ZAP • T15 moves closer to the ideal but remains outside the ZAP • T13 moves away from the ideal and remains outside the ZAP

Table 6.21: Classification of the 2nd class teachers in relation to their confidence

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T14
2	Outside ZAP	Inside ZAP	
3	Outside ZAP	Outside ZAP	T13, T15
4	Inside ZAP	Outside ZAP	

A matrix was created comparing teachers change in implementation (Table 6.19) with their change in confidence (Table 6.21), which is shown in Figure 6.43. T14 and T15 were successful in their implementation of the lessons at the end of the programme; however, T15 was not entirely confident. T13 was not very successful or confident in his implementation. The teachers' change in implementation and confidence is explored in more within these groups in the next section.

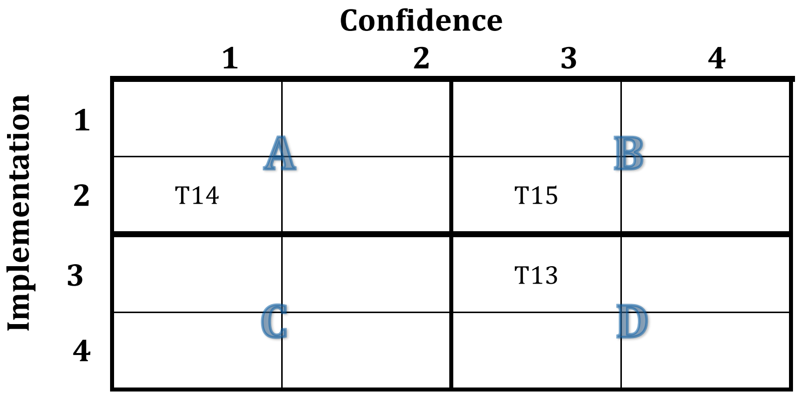

Figure 6.43: Overall classification of 2nd class teachers in relation to their implementation and confidence in teaching the CASE lessons

6.3.3 Analysis of 2nd Class Teacher Groups

The teachers were classified into groups based on the MDS analysis of their overall change in confidence and implementation of the CASE lessons. Each teacher will now be discussed within the group they were assigned to in Figure 6.43. However, all of the 2nd class teachers are represented on the same graph. Figure 6.44 presents the teachers' implementation versus confidence for each lesson and Figure 6.45 presents the teachers' implementation versus confidence for each pillar.

Group A

T14's implementation of the lessons varies throughout the programme, as shown in Figure 6.44. The MDS analysis of the teacher's lesson reflections indicates that the teacher is generally confident and successful in her implementation of the lessons at the end of tem three. However the teacher could improve in relation to both aspects. T14 is reasonably confident in her ability to implement the pillars of concrete preparation and cognitive conflict throughout the programme and the teacher is successful in her implementation of these pillars at the end of term three. T14 is entirely unsuccessful in her implementation of the pillar of metacognition throughout the programme, as shown in Figure 6.45.

Group B

The majority of the lessons implemented by T15 were reasonably successful; however the teacher was not very confident in her implementation, as shown in Figure 6.44. T15's implementation of the pillars of concrete preparation and cognitive conflict improved as the programme progressed, and these aspects of the lesson were reasonably successful at the end of term three. Again, the teacher was not very confident in her ability to implement these pillars successfully. The teacher's implementation of the pillar of metacognition is unsuccessful throughout the programme. At the end of term three, T15's implementation of this pillar decreases, however the teacher's confidence increases.

Group C

T13's implementation of the lessons was unsuccessful throughout the programme, and the teacher was not very confident, as shown in Figure 6.44. In relation to each pillar of the lesson, T13 was confident in his implementation of the pillars of concrete preparation and cognitive conflict at the beginning of term one; however the teachers' implementation of the pillar of cognitive conflict was unsuccessful. The teachers' implementation of the concrete preparation increased in term three, however the teacher was less confident. There was no change in the teacher's implementation of the pillar of cognitive conflict from term one to term three, however the teacher's confidence decreased. T13 was largely unsuccessful in their implementation of the pillar of metacognition throughout the programme. In term three, T13 decreased in relation to their confidence and implementation, as shown in Figure 6.45. However, towards the end of the programme, T13 left items in the lesson reflections blank, which may lead to inaccurate results for this teacher.

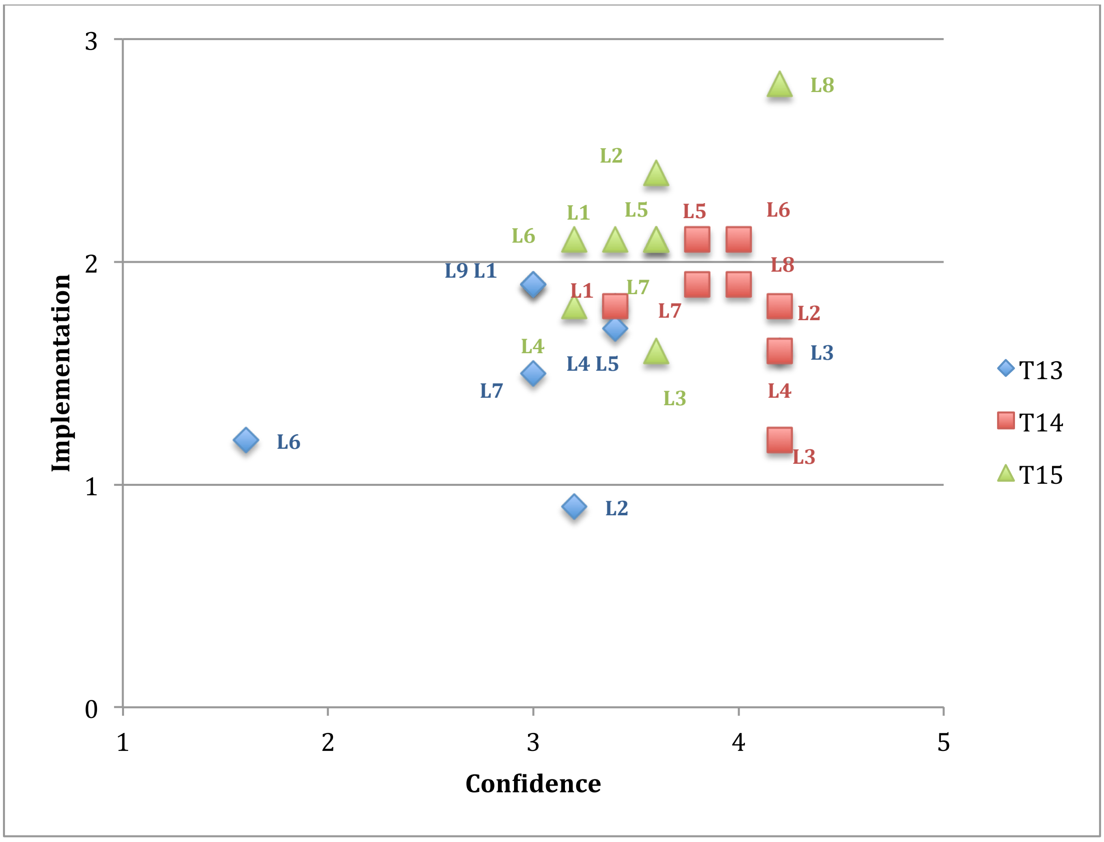

Figure 6.44: 2nd class teachers' implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.17

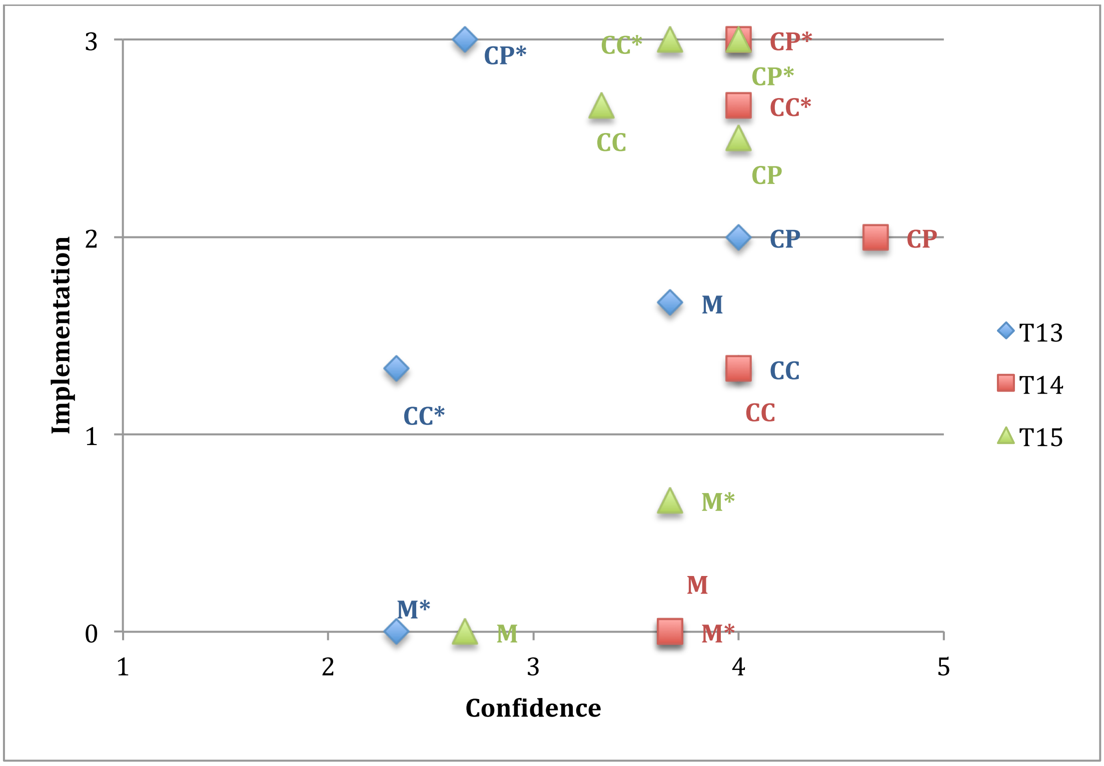

Figure 6.45: 2nd class teachers' implementation versus confidence for each pillar. Notation described in Table 6.7.

6.3.4 Researcher Observations for the 2nd Class Teachers

The 2nd class teachers' were observed between 3 – 4 occasions. The researcher's observations were compared with the teachers' responses to the lesson reflections as shown in Figure 6.46. The researcher's observations for T13 agree with the teacher's responses to the lesson reflections. Both sources suggest that the teacher's implementation of the lessons was unsuccessful. Three of the four observation ratings for T15 agree with the teacher's response to the lesson reflections. The researcher's observations for L8 indicate that the lesson was not as successful as suggested by the teacher's responses to the lesson reflections. If the researcher's observation is substituted in place of the rating generated from the lesson reflection (as described in Section 6.1.7), the point can be shifted, as shown in Figure 6.47. This movement of the lesson highlights that the teacher's implementation of the lesson remained successful.

T14 was observed on three occasions during the programme. Two of the three researcher's observations do not agree with the teacher's responses to the lesson reflections, as shown in Figure 6.46. Again, the researcher's observations were substituted in place of the rating generated from the lesson reflection, and the lessons moved accordingly, as shown in Figure 6.47. T14 tended to leave items in the lesson reflections blank or responded that she followed the lesson plan. This translation indicates that the teacher's implementation of the lessons was more successful than suggested by her responses to the lesson reflections.

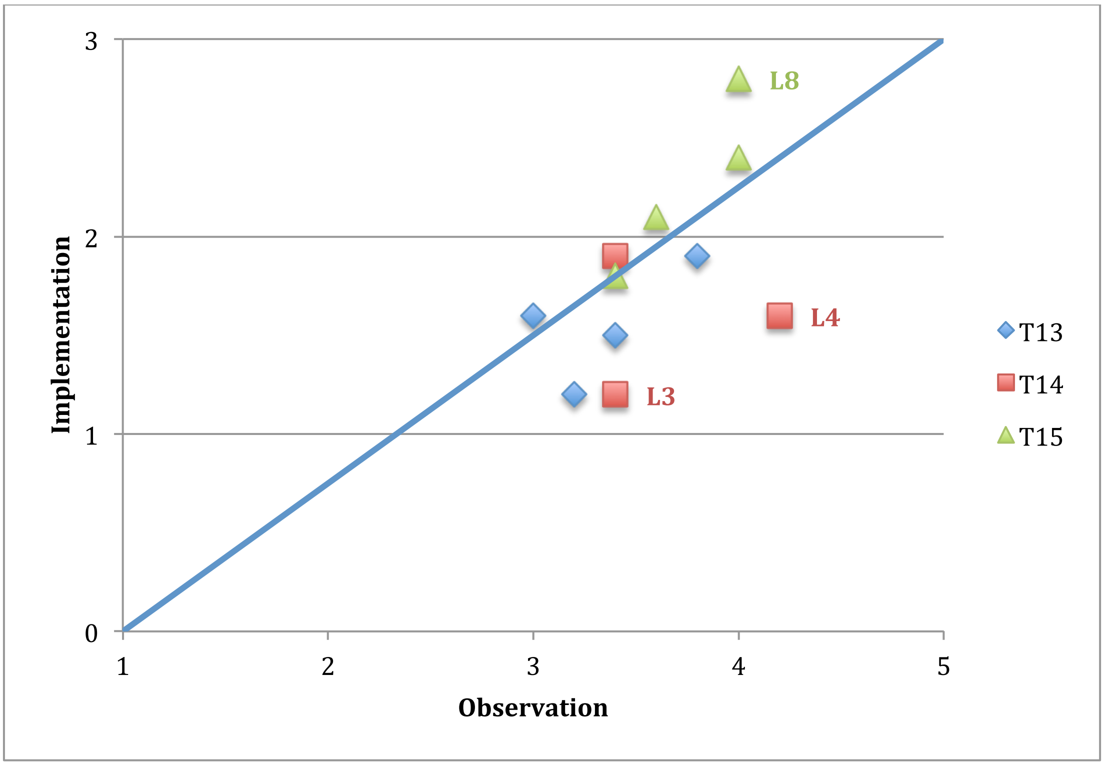

Figure 6.46: Researcher observations versus lesson implementation rating generated from the 2nd class teachers' responses to the lesson reflections

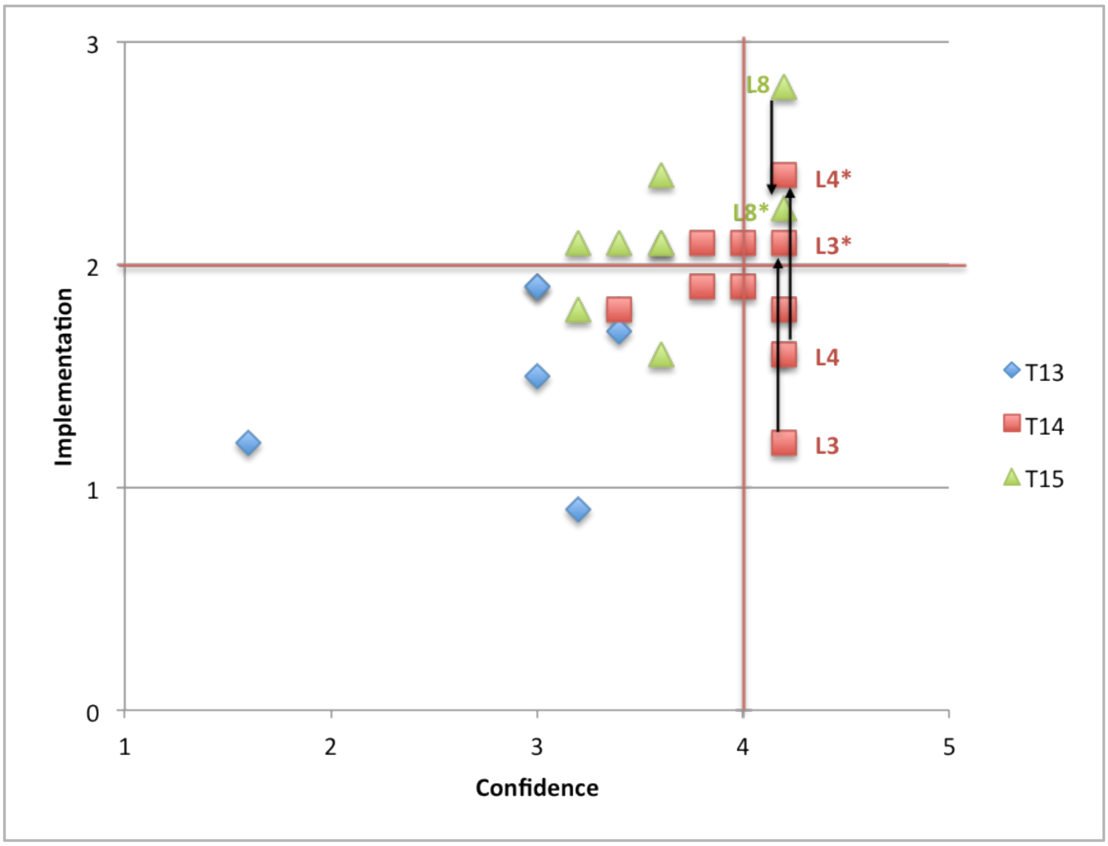

Figure 6.47: 2nd class teachers' implementation of the CASE lessons using the researcher's observation rating in place of the rating generated from the lesson reflections. The asterisk (*) beside the lesson code signifies the implementation using the researcher's observation.

6.3.5. 2nd class teachers' confidence in their understanding of the science content in the CASE lessons

The 2nd class teachers were generally confident in their understanding of the science content in the CASE lessons, as shown in Figure 6.48. T14 and T15 were consistently confident in their understanding of the science content in the lessons, as shown in Figure 6.48. T13 was not as confident in his understanding of science content in lessons L6, L7 and L9, and the teacher was unsuccessful in his implementation of theses lessons. However, T13 was confident in his understanding of the science content in the remaining lessons and was also unsuccessful in his implementation. This suggests that the teacher's confidence in his understanding of the science content in the lessons, did not effect his implementation of the lessons.

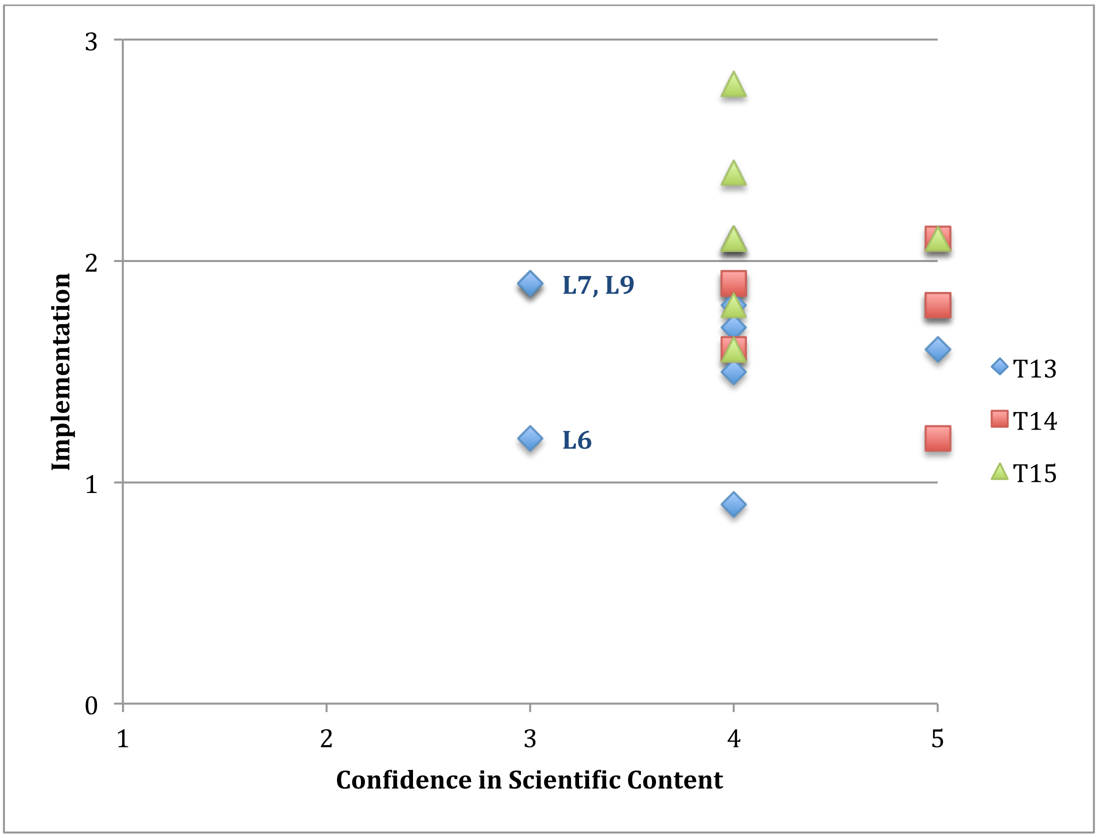

Figure 6.48: 2nd Class teachers' confidence in their understanding of the science content in the lessons versus their implementation

6.3.6 The 2nd class teachers and the CASE methodology overall

In general, the 2nd class teachers' management of the pillars of concrete preparation and cognitive conflict improved as the programme progressed, and at the end of the year, the teachers were successful in their implementation of both aspects. The teachers' implementation of the pillar of metacognition was largely unsuccessful and the teachers made no significant improvement in relation to this throughout the programme.

The 2nd class teachers had a positive attitude towards the CASE methodology and saw an improvement in their students' ability to articulate their thinking and work in groups (FG4). The lessons encouraged their students to "*focus more on the process, rather than the solution*" (T14.Q2) and to "*think and work independently*" (T15.Q2). The teachers felt that the science topics covered in the lessons integrated well with the curriculum topics but that "*the underlying thinking relates to all areas of learning*" (T14.Q2). The teachers found that their students began to participate more in class, offering opinions and solutions; however they continued to focus on the 'one right answer' and did not improve at this as the programme progressed (FG4). The students enjoyed the hands-on aspects of the lessons and working in groups; however, T16 felt her students struggled with the group-work aspect of the lessons (Q2). During the second term, the teachers were concerned that their students didn't understand the lessons.

> *I'm not sure if they get the point of it sometimes and I don't think they reach the level of thinking that the lessons want* (T13. FG3).

The teachers felt that they were also unfamiliar with the methodology and often did not know what questions to ask (FG3). The overall aim of the lessons, and the CASE methodology, was discussed in detail with the teachers so that they felt more confident in their ability to guide their students through the pillars of the lesson (FG3). At the end of the year, T14 and T15 reported that they felt confident in their knowledge of the methodology and their ability to implement the lessons successfully; however, T13 was not very confident (Q2). The teachers found team-teaching beneficial and helped them with their implementation of the lessons.

I'm able to see how you managed the lesson and can try some of the things you did like rephrasing the question to get the right answer (T15. FG3).

The teachers' inability to elicit metacognitive thinking from their students indicates that they require further support in understanding the CASE methodology particularly in relation to the concept of metacognition.

6.4 Senior Infants and First Class Teachers

6.4.1 Overview

The Senior Infant and 1st class group consists of eight teachers, as shown in Table 6.22. During the whole school implementation, T12, who participated in the pilot programme, implemented lessons, took part in focus group discussions and completed Q1. However the teacher only completed 4 lesson reflections, all of which were at the beginning of the programme and was therefore not considered as part of this analysis.

Table 6.22: Teachers of Senior Infants and 1st class

Senior Infants	1st Class
T5	T9
T6	T10
T7	T11
T8	T12

As with the 4th and 6th class groups, it was not considered appropriate to start the 1st class students half way through a CASE programme. The 1st class teachers implemented the first 9 lessons from the Senior Infants programme so that the students could gain an understanding of the underlying schema involved and become familiar with the cognitive acceleration methodology. Following this, the 1st class teachers continued on to the 1st class programme. However, the Senior Infant teachers only implemented L1- L6 from the Senior Infant programme. When introducing the teachers to the lessons in Focus Group 3, they felt that the later lessons were too difficult for their students. T6 attempted to implement the lesson *'Farm Animals 1'* with a group of her more able students but felt that they could not grasp the lesson and needed a lot of guidance. *"They weren't able for it. They could group them into colours and animals but they couldn't get the grid even with my help" (T6.FG4).* The teachers felt that the lessons were not suitable for use in Senior Infants and, therefore, the teachers began teaching the lessons at the end of the Junior Infant programme in the second term. Therefore, lessons 1-6 are the same for both class groups. Lessons 1-3 are introductory lessons and were not considered in the MDS analysis. The lessons completed by each teacher and the lesson reflections received are presented in Tables 6.23 and 6.24.

Table 6.23: Lessons completed and lesson reflections received for the Senior Infants teachers (✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		Senior Infants			
		T5	**T6**	**T7**	**T8**
L1	Clown Faces	✓	✓	✓	✓
L2	Space	✓	✓	✓	✓
L3	Animals	✓	✓	✓	✓
L4	Sticks	✓	✓	✓	✓
L5	Marble Run	✓	✓	✓	✓
L6	Sorting Shapes	✓	✓	✓	✓
L7	Who Are We?	✓	✓	✓	✓
L8	Sort Us Out	✓	✓	✓	✓
L9	Enjoying Ourselves	✓	✓	✓	✓
L10	Our Birthdays	O	O	O	O
L11	We watch TV	✗	✗	✗	✗
Total Lesson Reflections Received		9	9	9	9

Table 6.24: Lessons completed and lesson reflections received for the First class teachers (✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		First Class			
		T 9	**T10**	**T11**	**T12**
L1	Clown Faces	✓	✓	✓	✓
L2	Space	✓	✓	✓	✓
L3	Animals	✓	✓	✓	O
L4	Sticks	✓	✓	✓	✓
L5	Marble Run	✓	✓	✓	✓
L6	Sorting Shapes	O	O	✓	O
L7	Farm Animals 1	✓	✓	✓	O
L8	Farm Animals 2	✓	✓	✓	O
L9	Lost Boot	O	O	O	✗
L10	Boxes	✓	✓	✓	✗
L11	Crossroads	✗	✗	✗	✗
L12	Bricks	O	✓	O	✗
L13	Rolling Bottles	✗	✗	✗	✗
L14	In this Town	✓	✓	✓	✗
L15	Rules of a game	✗	✓	✗	✗
Total Lesson Reflections Received		9	11	10	4

A timeline of the Senior Infant and 1st class groups' implementation of the CASE lessons is presented in Figure 6.49.

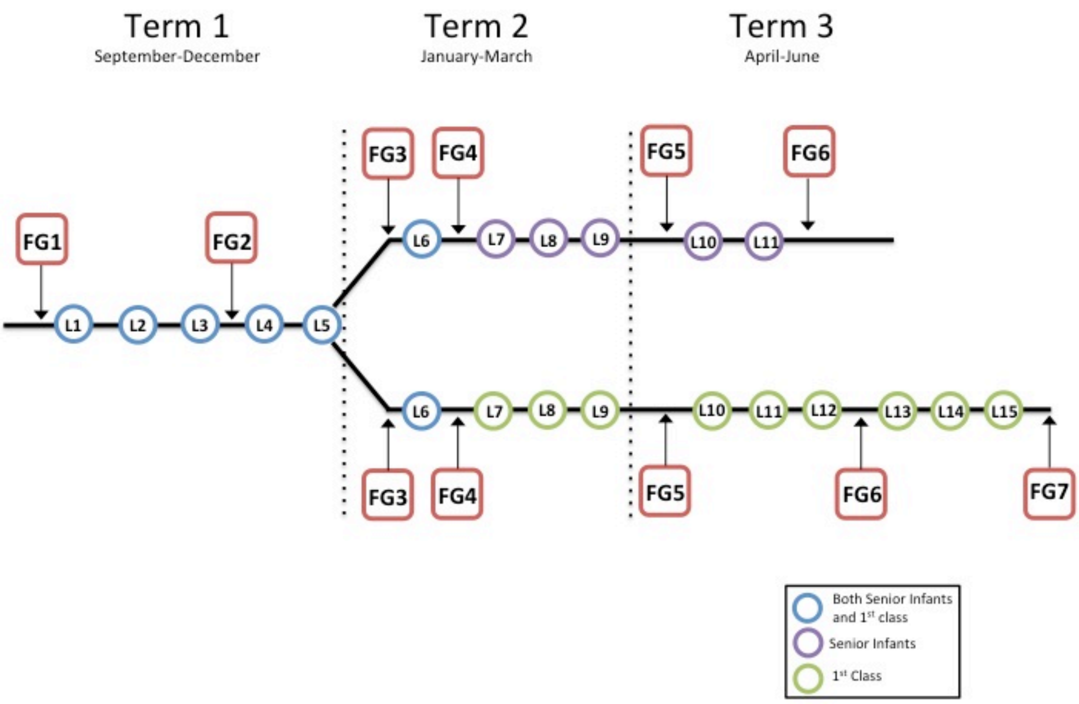

Figure 6.49: Timeline for the Senior Infants and 1st class groups' implementation of the CASE lessons

The CASE activities at this class level are designed to be carried out with a small group of students each day. Each activity lasts approximately 30 minutes. At the end of the first term, the Senior Infant and 1st class teachers did not feel that they could fit the CASE activities in with their workload. The teachers had a positive attitude towards the CASE methodology, and could see the benefit of implementing the activities with small groups; however, they felt that this arrangement was too time consuming and cited curriculum overload as the main reason for this. *"For us, it's two and a half hours teaching which works out as only half an hour per child and it's just not efficient" (T6. FG3).* Therefore, lessons carried out in the second and third terms (lessons 6-11 for Senior Infants and 6-15 for 1st class) were carried out as whole class activities. Teachers spent longer on each activity and moved around the classroom facilitating group discussions. In Focus Group 5, both sets of teachers expressed that this new format was working better for them. They acknowledged that while doing the activities in small groups was of greater benefit to the students, they felt it was better to implement the lessons as whole group activities rather than omitting them entirely. It was suggested to the teachers that they implement the lessons together with a learning support teacher to facilitate group discussions and to ensure that the students were engaged in so far as possible.

6.4.2 Multidimensional scaling

The data obtained from the Senior Infant and 1st class teachers was analysed with regard to their implementation and confidence, as already described in the previous sections of this chapter. As with the previous groups the introductory activities *"Clown Faces"*, "*Space*" and "*Animals*" were not taken into account in this analysis. Figure 6.50, Table 6.25 and Table 6.26 summarise the teachers' change in implementation with regard to the ZAP, and Figure 6.51, Table 6.27 and Table 6.28 summarise the teachers' change in confidence in a similar manner.

a) Implementation

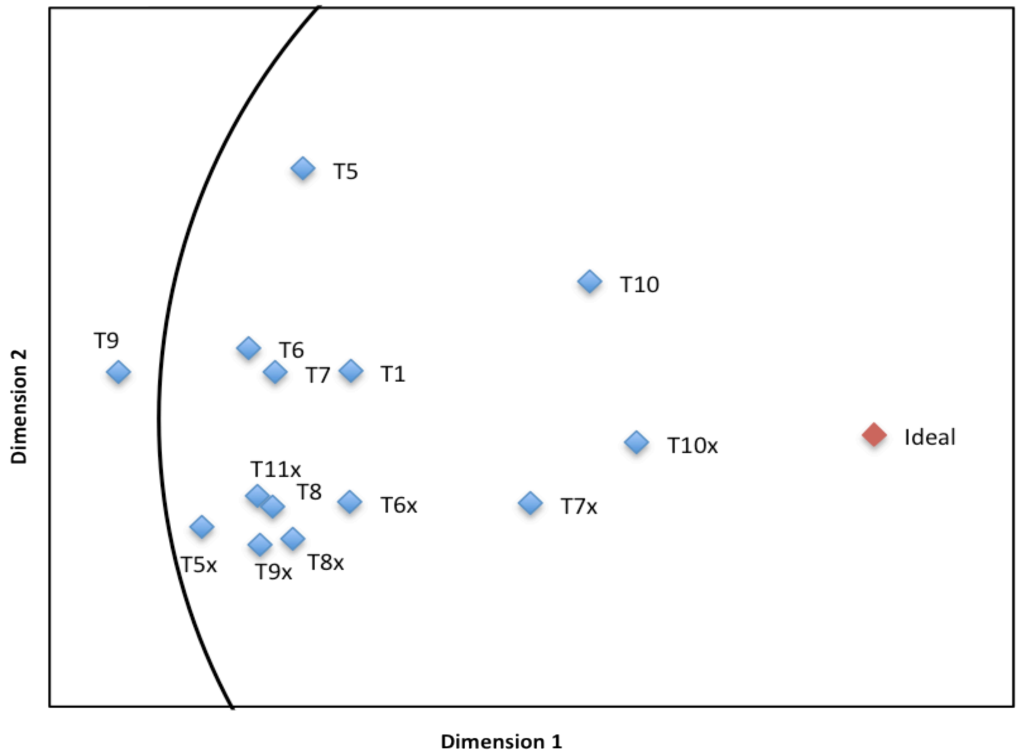

Figure 6.50: Senior Infants and 1st class teachers' change in implementation relative to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.

Table 6.25: Senior Infants and 1st class teachers' change in implementation from term one to term three

Implementation	
Term 1	**Term 3**
• T5, T6, T7, T8, T10 and T11 are situated within the ZAP • T10 is the closest to the ideal • T9 is situated just outside ZAP	• T7 and T10 move towards the ideal • T5, T6, T8, T11 do not move significantly closer to the ideal and form a cluster of points within the ZAP • T9 moves towards the ideal and into this cluster

Table 6.26: Classification of the Senior Infant and 1st class teachers in relation to their implementation

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T5, T6, T7, T8, T10, T11
2	Outside ZAP	Inside ZAP	T9
3	Outside ZAP	Outside ZAP	
4	Inside ZAP	Outside ZAP	

b) Confidence

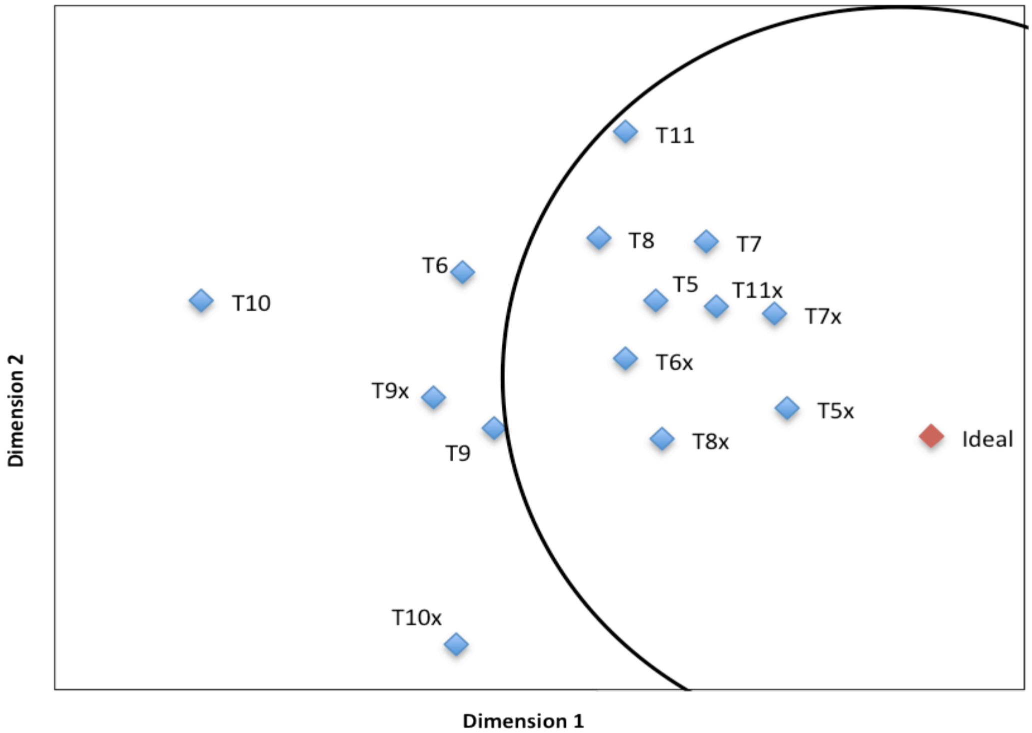

Figure 6.51: **Senior Infants and 1st class teachers' change in confidence relative to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.**

Table 6.27: Senior Infants and 1st class teachers' change in confidence from term one to term three

Confidence	
Term 1	**Term 3**
• T5, T7, T8 and T11 are situated within the ZAP • T6, T9 and T10 are located just outside the ZAP • T10 is furthest from the ideal	• T5, T7, T8 and T11 move closer to ideal and remain in the ZAP • T6 moves closer to the ideal and into the ZAP • T9 and T10 remain outside the ZAP

Table 28: Classification of the Senior Infant and 1st class teachers in relation to their confidence

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T5, T7, T8 T11
2	Outside ZAP	Inside ZAP	T6
3	Outside ZAP	Outside ZAP	T9, T10
4	Inside ZAP	Outside ZAP	

A matrix was created comparing teachers change in implementation (Table 6.26) with their change in confidence (Table 6.28), which is shown in Figure 6.52. All of the teachers are situated in Groups A and B indicating that they were successful in their implementation of the lessons at the end of the programme. However, T9 and T10 were not confident in their implementation. The teachers' change in implementation and confidence is explored in more within these groups in the next section.

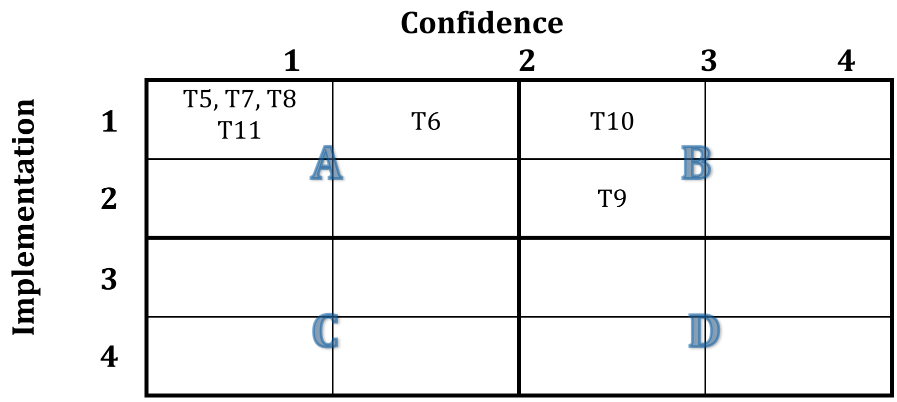

Figure 6.52: Overall classification of Senior Infants and 1st class teachers in relation to their implementation and confidence in teaching the CASE lessons

6.4.3 Analysis of Senior Infant and 1st class teacher groups

The teachers were classified into four groups based on the MDS analysis of their overall change in confidence and implementation of the CASE lessons. Each teacher will now be discussed within the group they were assigned to in Figure 6.52.

Group A

All five teachers in Group A were successful in their implementation of the lessons at the end of the programme. However, each teacher's progress varied. T7 and T8 were consistently successful in their implementation of the lessons and their confidence increased towards the end of the year. T5, T6 and T11 improved in their confidence and implementation of the lessons as the year progressed, as shown in Figure 6.53.

All of the teachers were confident and successful in their implementation of the pillars of concrete preparation and cognitive conflict throughout the programme. However, Figure 6.54 clearly shows that the teachers were entirely unsuccessful in their implementation of the pillar of metacognition and that the teachers were generally not very confident. The teachers generally made no improvements in relation to their implementation of this pillar as the programme progressed.

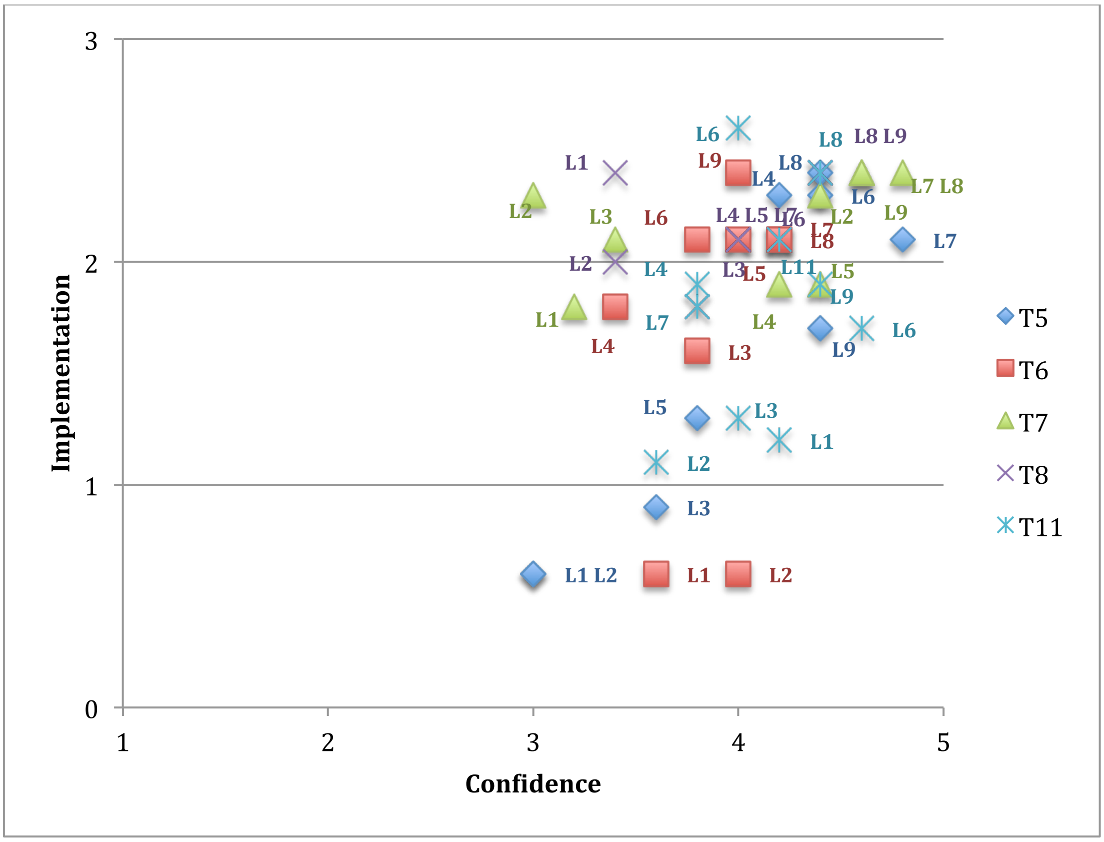

Figure 6.53: Senior Infants and 1st class teachers' (Group A) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.23 and Table 6.24.

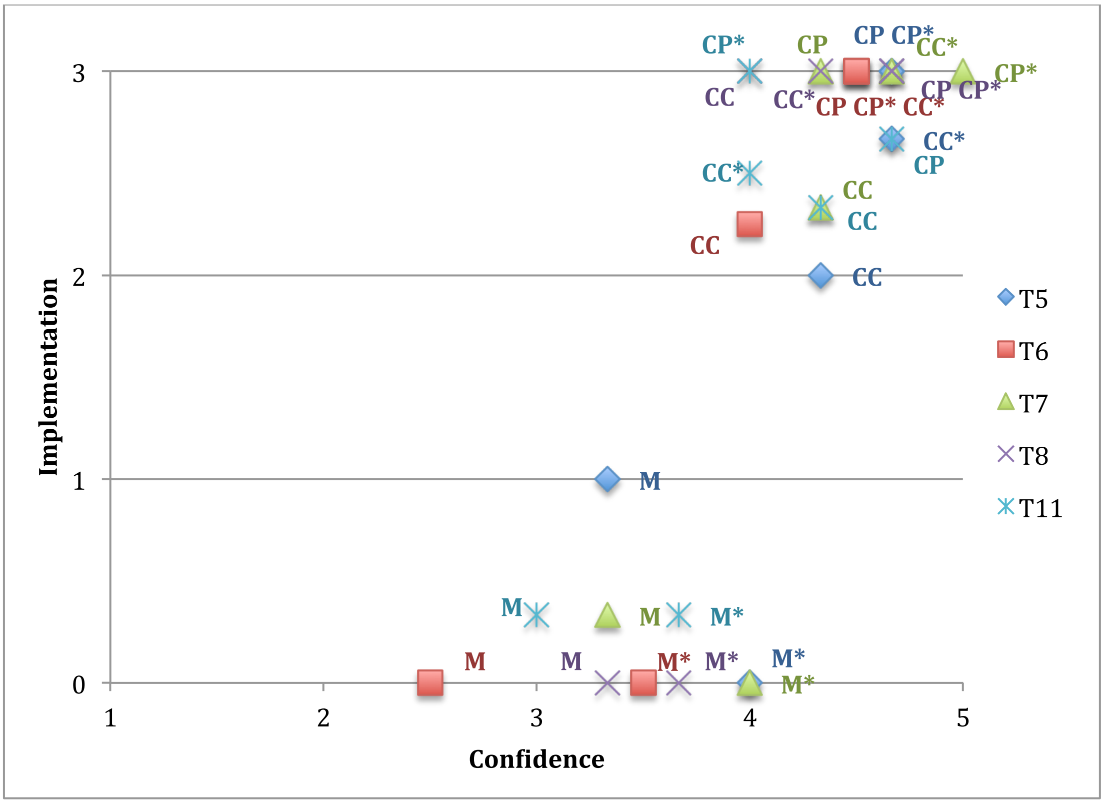

Figure 6.54: Senior Infants and 1st class teachers' (Group A) implementation versus confidence for each pillar. Notation described in Table 6.7.

Group B

T9 and T10 were successful in their implementation of the CASE lessons at the end of the year. T10 was consistent in her implementation while T9 improved as the programme progressed. However, both teachers were not very confident in their implementation, as shown in Figure 6.55. T10 was successful in her implementation of the pillars of concrete preparation and cognitive conflict throughout the programme, however the teacher was not very confident in relation to both aspects, as shown in Figure 6.56. The teacher's implementation of the pillar of metacognition improved towards the end of the programme and the teacher was reasonably confident and successful in her implementation of this pillar. T9 was successful in her implementation of the pillars of concrete preparation and cognitive conflict throughout the programme, although the teacher's confidence decreased slightly towards the end of the year. At the beginning of term one, T9 was entirely unsuccessful in her implementation of the pillar of metacognition and the teacher did not improve at this by the end of term three.

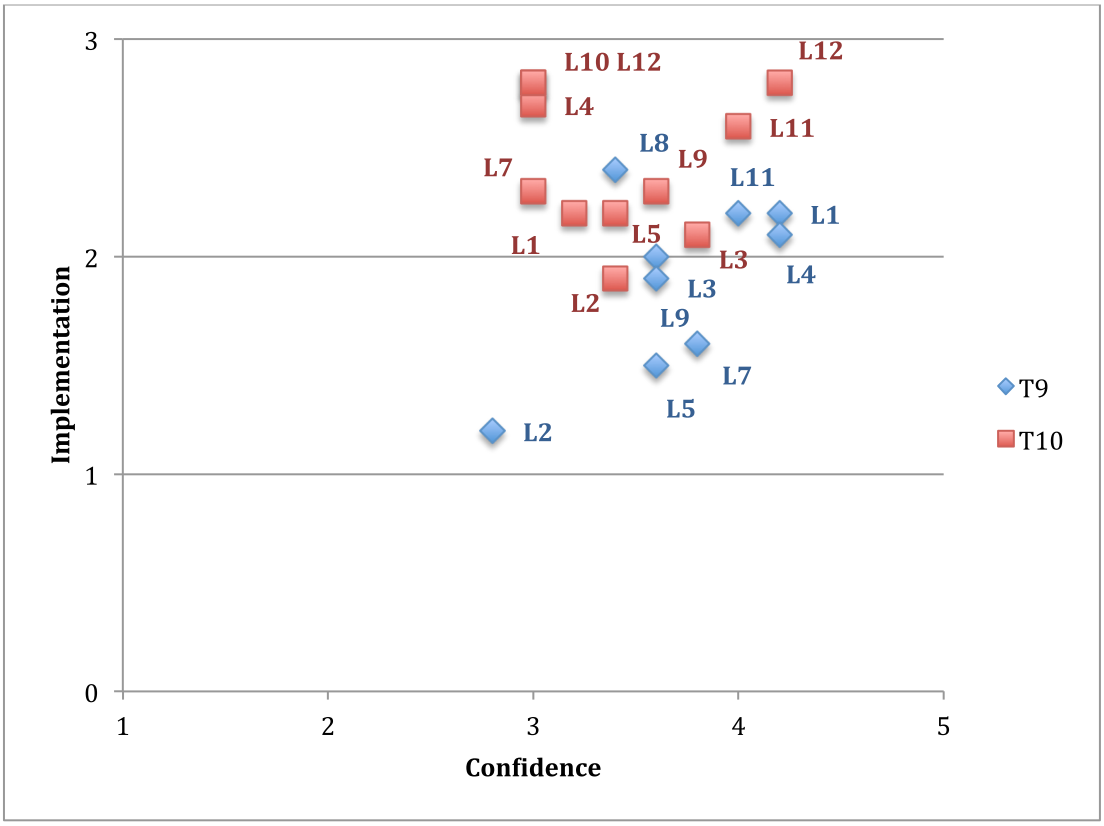

Figure 6.55: Senior Infants and 1st class teachers' (Group B) implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.23 and Table 6.24.

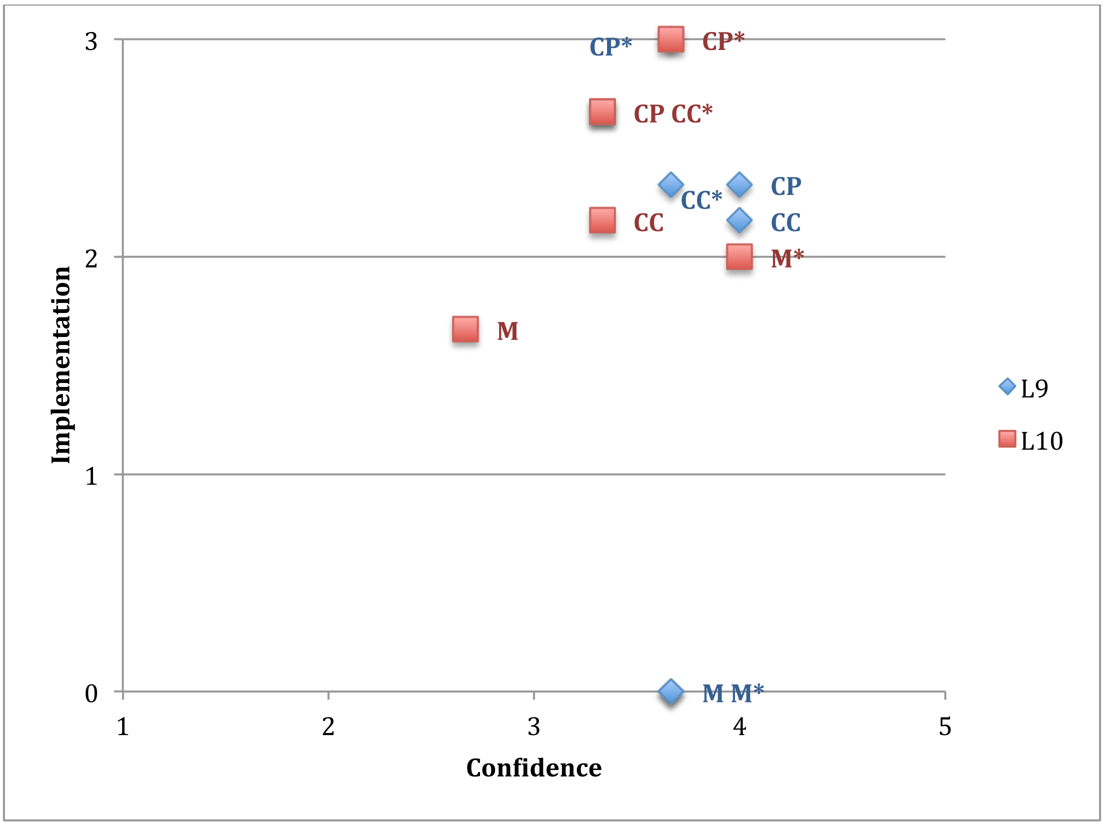

Figure 6.56: Senior Infants and 1st class teachers' (Group B) implementation versus confidence for each pillar. Notation described in Table 6.7.

6.4.4. Senior Infant and 1st class teachers' confidence in their understanding of the science content in the CASE lessons

The Senior Infant and 1st class teachers' confidence in their understanding of the science content was compared to their implementation of the lessons, as shown in Figures 6.57 and 6.58. As previously mentioned, L1 – L6 are the same for both groups of teachers. The Senior Infant teachers were generally confident in their understanding of the content in the CASE lessons, as shown in Figure 6.57. However, T5, T6 and T8 are not very confident in their understanding of the science content covered in L2 (*Space*). The lesson '*Space'* is an introductory activity designed to develop the students' listening and group-work skills and does not explicitly cover any scientific content. In the lesson reflections, the teachers responded that their students found the vocabulary used in this lesson difficult, which may explain the teachers' lack of confidence in their understanding. The Senior Infant teachers were generally confident in their scientific understanding in relation to the remaining lessons. Despite this, teachers' implementation of the lessons varied and some lessons were largely unsuccessful.

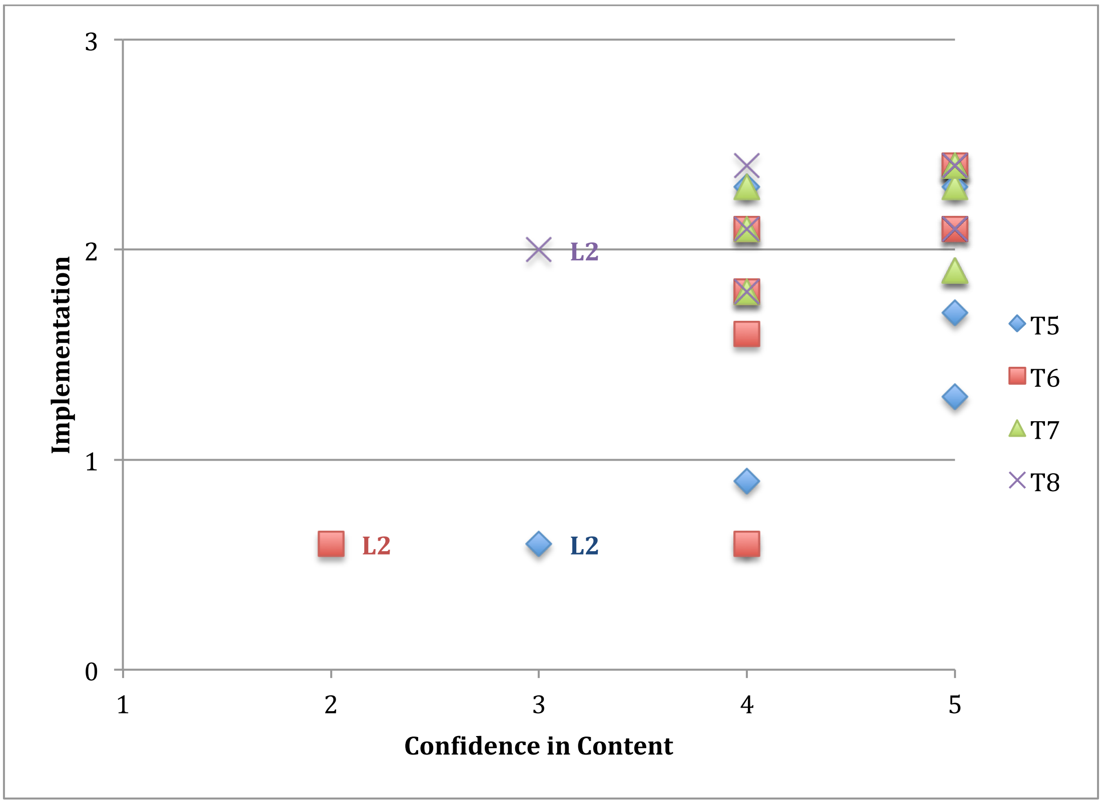

Figure 6.57: Senior Infant teachers' confidence in their understanding of the science content in the lessons versus their implementation

The 1st class teachers were less confident in their understanding of the science content than the Senior Infant teachers, as shown in Figure 6.58. The lessons in the *Let's Think! 5&6* programme, implemented by the 1st class teachers, focus on the schemata of concrete operations and do not cover any science content. The teachers' apparent lack of confidence in their understanding of the science content may be as a result of the teachers' unfamiliarity with the lessons, rather than a lack of scientific knowledge. Despite her lack of confidence, T10 was generally successful in her implementation of the lessons.

T11's confidence in her understanding of the science content varied for each lesson. Lessons in which the teacher was confident in her understanding of the science content were implemented with greater success than those in which the teacher was not very confident. However, the teacher was not very confident in her understanding of the science content in L14 and the teacher was reasonably successfully in her implementation. T9's confidence also varied, and the teacher was not very confident in her understanding of the science content in L7, L8, L10 and L14. Again, these lessons do not cover any science content and suggest that the teacher was not familiar with the lesson. T9 was also not very confident in her ability to implement the lessons, as shown in Figure 6.58. This analysis suggests that 1st class teachers may not be confident in their understanding of the methodology or unfamiliar with the lessons, rather than lacking the scientific content knowledge and would benefit from becoming more familiar with the lessons prior to implementing them.

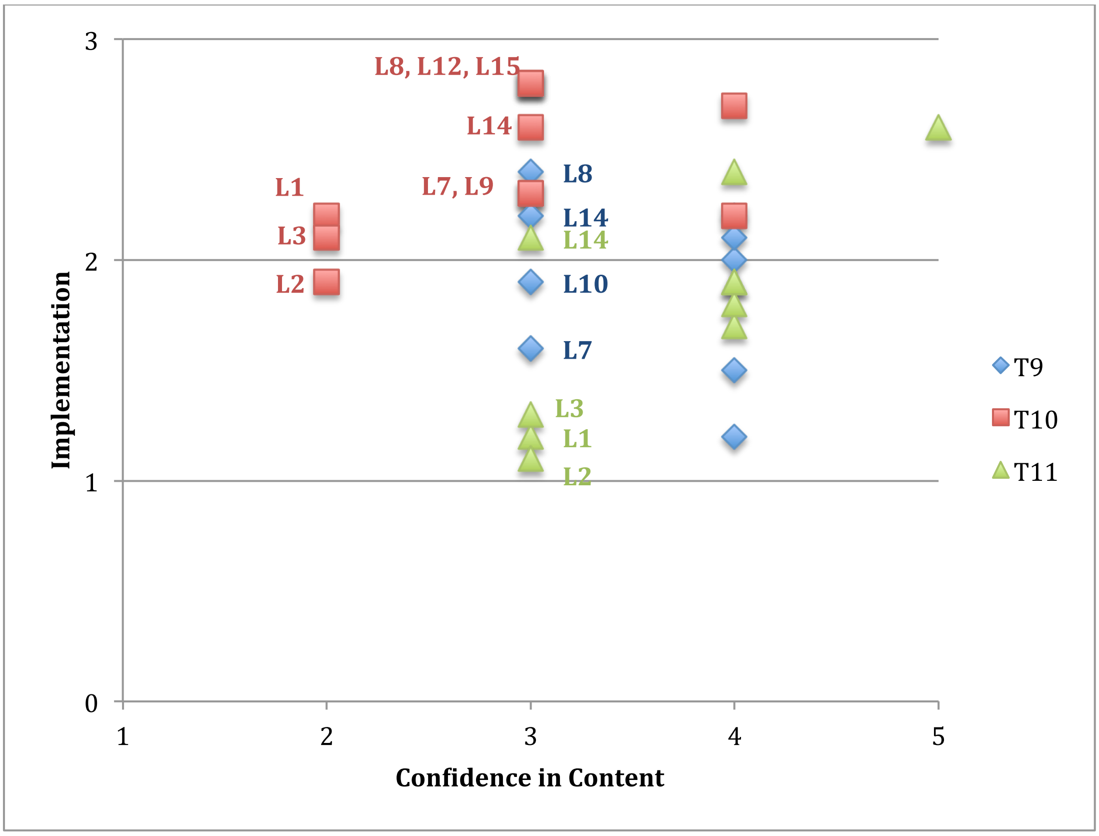

Figure 6.58: 1st class teachers' confidence in their understanding of the science content in the lessons versus their implementation

6.4.5 The Senior Infant and 1st class teachers and the CASE methodology overall

The Senior Infant and 1st class teachers had a positive attitude towards the CASE methodology. They felt that the lessons really challenged their students to think for themselves, which they enjoyed (FG6). The students' ability to work in groups improved as the programme progressed, however they still tended to focus on the 'one right answer' (Q2). The teachers also felt that, in trying to articulate their thinking, the students developed their oral language skills (FG2). The teachers were generally confident in their understanding of the CASE methodology and in their ability to guide their students through the activities at the end of the programme (Q2).

As a result of teaching the lessons, the teachers felt that they were more conscious of their student's thinking.

> *I will be more thorough in the future in assessing, monitoring and encouraging their thinking skills* (T8. Q2).

During term 1, the teacher's found it difficult not to "*jump in*" and tell the students the answers (FG2) however the teacher's felt that they improved at this as the programme progressed (Q2).

> *The lessons have stopped me spoon feeding them as much because I can see that they're able to think for themselves* (T5. Q2).

T12 stated that once she slowed the lesson down she realised "*it's not about the doing but the thinking*"(FG3). According to T12, putting the focus on the student is "*slightly aspirational for the teacher under pressure but having done (*the lessons*) the value jumps out at you. It has seriously impacted on the rest of my teaching*" (T12.L5). The Senior Infant and 1st class teachers felt that their questioning skills had also improved and that this had transferred to other lessons (FG5).

> *Higher order questioning was a factor in a lot of the lessons and I enjoyed practicing with these questions and felt my confidence improved using these questions* (T8. Q2)

All of the teachers felt that the implementation of the CASE programme was more manageable when the activities were conducted as whole class lessons. The teachers moved around the classroom facilitating group discussions and encouraging whole class discussions. Although this was not ideal, the lessons were carried out successfully. The importance of creating mixed ability groups was discussed with the teachers. The teachers also tried to implement the CASE activities when there was a learning support teacher present to help facilitate group discussions (FG6).

The Senior Infant teachers also found the activities from the Junior Infant programme were more suited to their students' level, although still challenged the children. Therefore, the Senior Infant programme has been adapted, as shown in Table 6.29.

Table 6.29: Final set of lessons for the Senior Infant and First class groups

	Senior Infants	First Class
1	Clown Faces	Farm Animals 1
2	Space	Buttons
3	Animals	Farm Animals 2
4	Who Are We?	Lost Boot
5	Sort Us Out	Boxes
6	Enjoying Ourselves	Cooking
7	Our Birthdays	Living
8	We watch TV	Guess What
9	Sticks	Crossroads I
10	Flowers	Looking at Shapes
11	Marble Run	Crossroads II
12	Sorting Shapes	Bricks
13		The Cat and the Snail
14		Shadows
15		In this Town
16		Making a Game
17		Transformations
16		Farmyard
19		The ice-cream story

6.5 Junior Infants Teachers

6.5.1 Overview

The Junior Infant group consists of four teachers, as shown in Table 6.30. T2 participated in the pilot study.

Table 6.30: Junior Infant class teachers

Junior Infants
T1
T2
T3
T4

The Junior Infant teachers did not begin implementing the CASE lessons until the second term to allow their students an appropriate amount of time to settle into the classroom environment. T4 took part in focus group discussions but did not complete Q1 and Q2 or any of the lesson reflections. T1, T2 and T3 completed six lesson reflections each. The lessons completed and lesson reflections received from each teacher is presented in Table 31.

Table 6.31: Lessons completed and lesson reflections received for the Junior Infants teachers(✓ = Lesson completed and lesson reflection received; O = Lesson completed but no lesson reflection received; ✗ = Lesson not completed)

		Junior Infants			
		T1	T2	T3	T4
L1	Colourful Flowers	✓	✓	✓	O
L2	Where do I live?	✓	✓	✓	O
L3	What do I eat?	✓	✓	✓	O
L4	My Senses	✓	✓	✓	O
L5	Castles at the seaside	✓	✓	✓	O
L6	At the seaside	✓	✓	✓	✗
L7	Mixed-up stories	✗	✗	✗	✗
L8	Where are my toys?	✗	✗	✗	✗
L9	How do my toys move?	✗	✗	✗	✗
L10	Holes	✗	✗	✗	✗
Total Lesson Reflections Received		6	6	6	0

A timeline of the Junior Infant class group's implementation of the CASE lessons is presented in Figure 6.59.

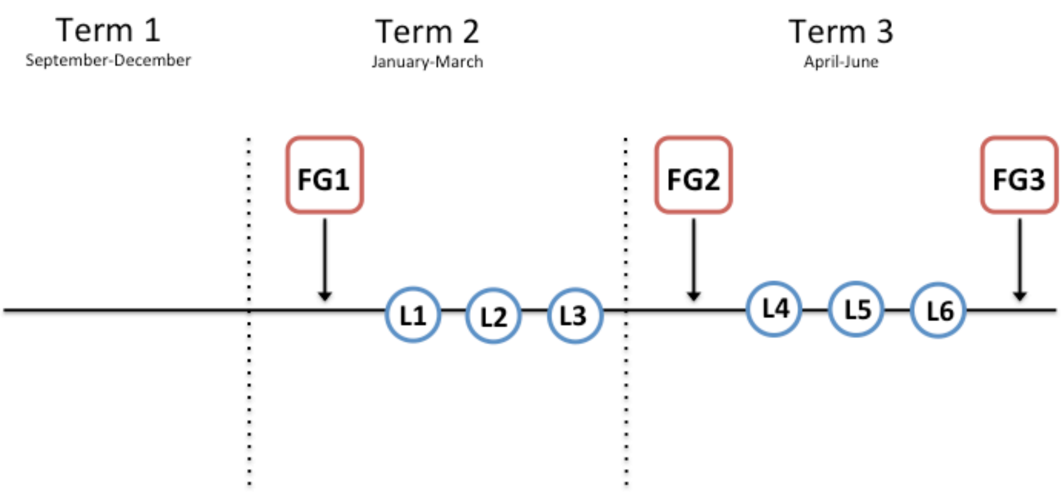

Figure 6.59: Timeframe for the Junior Infants class groups' implementation of the CASE lessons

6.5.2 Multidimensional scaling analysis

Again, the teachers' lesson reflections underwent MDS analysis to examine any change in their implementation or confidence. The data obtained from the Junior Infant teachers was analysed with regard to their implementation and confidence, as already described in the previous sections of this chapter. Figure 6.60, Table 6.32 and Table 6.33 summarise the teachers' change in implementation with regard to the ZAP, and Figure 6.61, Table 6.34 and Table 6.35 summarise the teachers' change in confidence in a similar manner.

a) Implementation

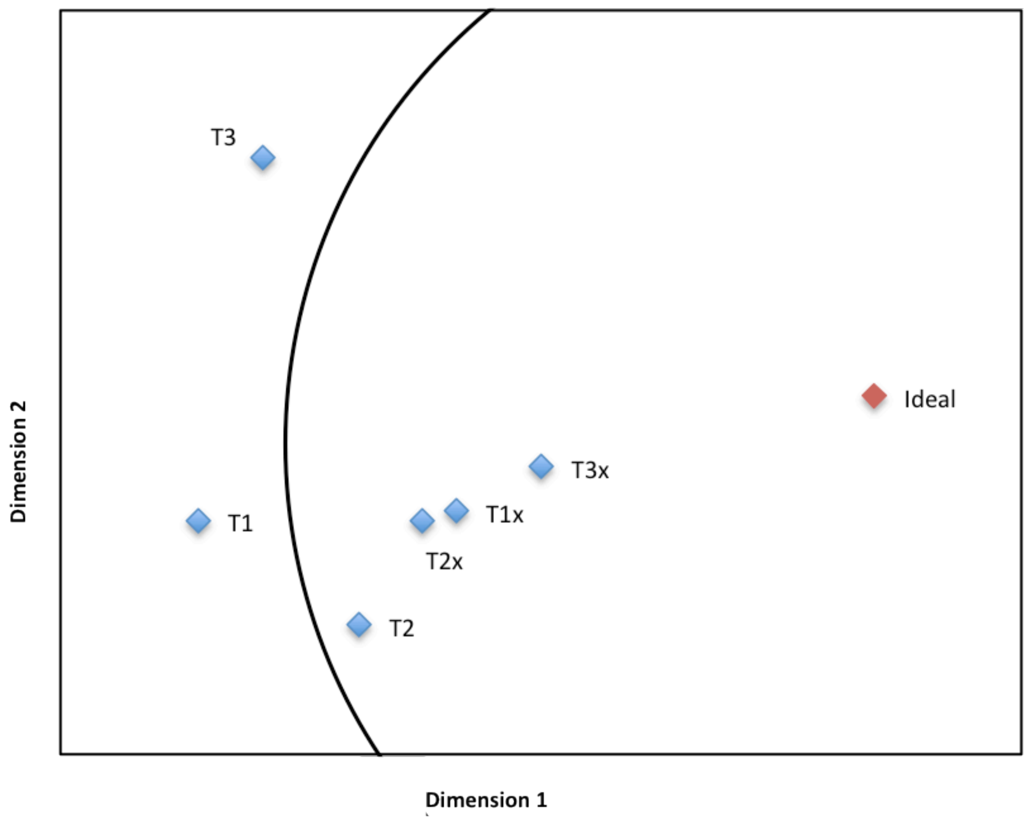

Figure 6.60: Junior infant teachers' change in implementation relative to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.

Table 6.32: Junior Infants teachers' change in implementation from term one to term three

Implementation	
Term 1	**Term 3**
• T2 is situated at the boundary for the ZAP • T1 and T3 are situated just outside the ZAP	• T2 remains within the ZAP and moves closer to the ideal • T1 and T3 move closer to the ideal and into the ZAP

Table 6.33: Classification of Junior Infant teachers in relation to their implementation

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T2
2	Outside ZAP	Inside ZAP	T1, T3
3	Outside ZAP	Outside ZAP	
4	Inside ZAP	Outside ZAP	

b) Confidence

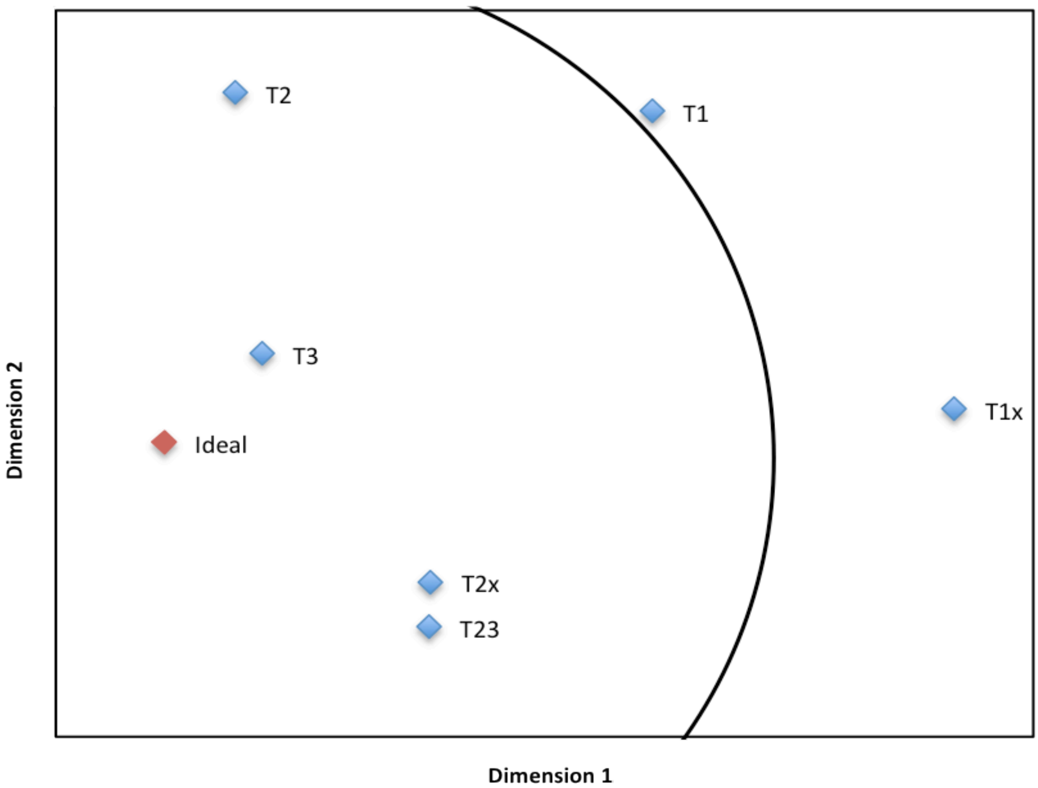

Figure 6.61: **Junior Infant teachers' change in confidence relative to the ZAP from the term one to term three. The 'x' beside the teacher code indicates the teacher's position in term three.**

Table 6.34: Junior Infants teachers' change in confidence from term one to term three

Confidence	
Term 1	**Term 3**
• T2 and T3 are situated within the ZAP • T1 is situated just outside the ZAP	• T2 and T3 remain within the ZAP. • T1 moves slight away from the ideal and remains outside the ZAP

Table 6.35: Classification of Junior infant teachers in relation to their confidence

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T2, T3
2	Outside ZAP	Inside ZAP	
3	Outside ZAP	Outside ZAP	T1
4	Inside ZAP	Outside ZAP	

The matrix comparing the Junior Infants teachers' change in implementation with their change in confidence is shown in Figure 6.62.

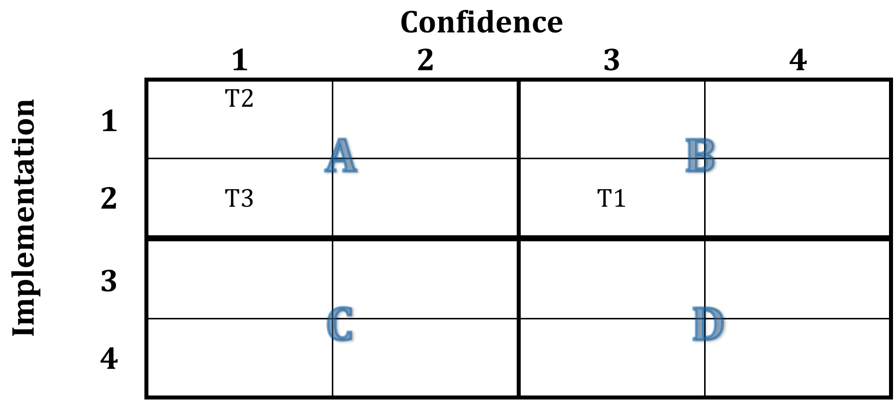

Figure 6.62: Overall classification of Junior Infant teachers in relation to their implementation and confidence in teaching the CASE lessons

6.5.3 Analysis of Junior infant teacher groups

The teachers were classified into groups based on the MDS analysis of their overall change in confidence and implementation of the CASE lessons. Each teacher will now be discussed within the group they were assigned to in Figure 6.62. All of the Junior Infant teachers are represented on the same graph. Figure 6.63 presents the teachers' implementation versus confidence for each lesson and Figure 6.64 presents the teachers' implementation versus confidence for each pillar.

Group A

T2 was generally confident in her implementation of the lessons throughout the programme; however the teacher was slightly less confident in her implementation of L5 "*Castles in the Sand*". The teacher's implementation of the lessons was not entirely successful throughout the programme, although the teacher was successful in her implementation of L3, L4 and L6. T2 was confident and successful in her implementation of the pillars of concrete preparation and cognitive conflict throughout the programme. The teacher was entirely unsuccessful in her implementation of the pillar of metacognition throughout the programme; however the teacher was consistently confident, as shown in Figure 6.64.

T3 improved in her implementation of the lessons as the programme progressed, as shown in Figure 6.63. The teacher was largely confident throughout the programme; however, she was slightly less confident in her implementation of L5. T3 was consistently successful and confident in her implementation of the pillars of concrete preparation and cognitive conflict, although the teacher's confidence decreased slightly for the last three lessons implemented. The teacher was largely unsuccessful in her implementation of the pillar of metacognition throughout the programme; however, the teacher was confident, as shown in Figure 6.64.

Group B

T1 was not very confident and unsuccessful in her implementation of L1, as shown in Figure 6.63. However subsequent lessons implemented by the teacher were reasonably successful, although the teacher's confidence varied throughout the programme. The teacher was successful in her implementation of the pillar of concrete preparation throughout the programme and improved in her implementation of the pillar of cognitive conflict, as shown in Figure 6.64. However, the teacher was not very confident in relation to both aspects. The teacher's implementation of the pillar of metacognition was entirely unsuccessful throughout the programme.

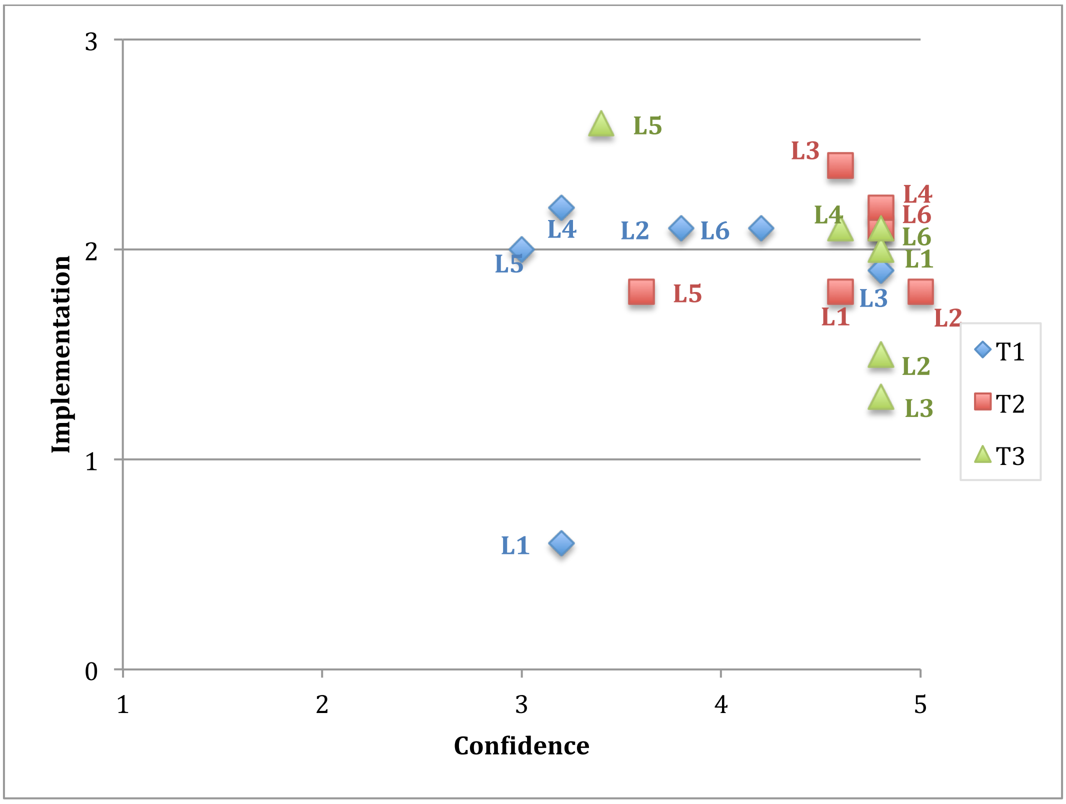

Figure 6.63: Junior Infant teachers' implementation versus confidence for each lesson (L). Lesson numbers correspond with the set of lessons presented in Table 6.31

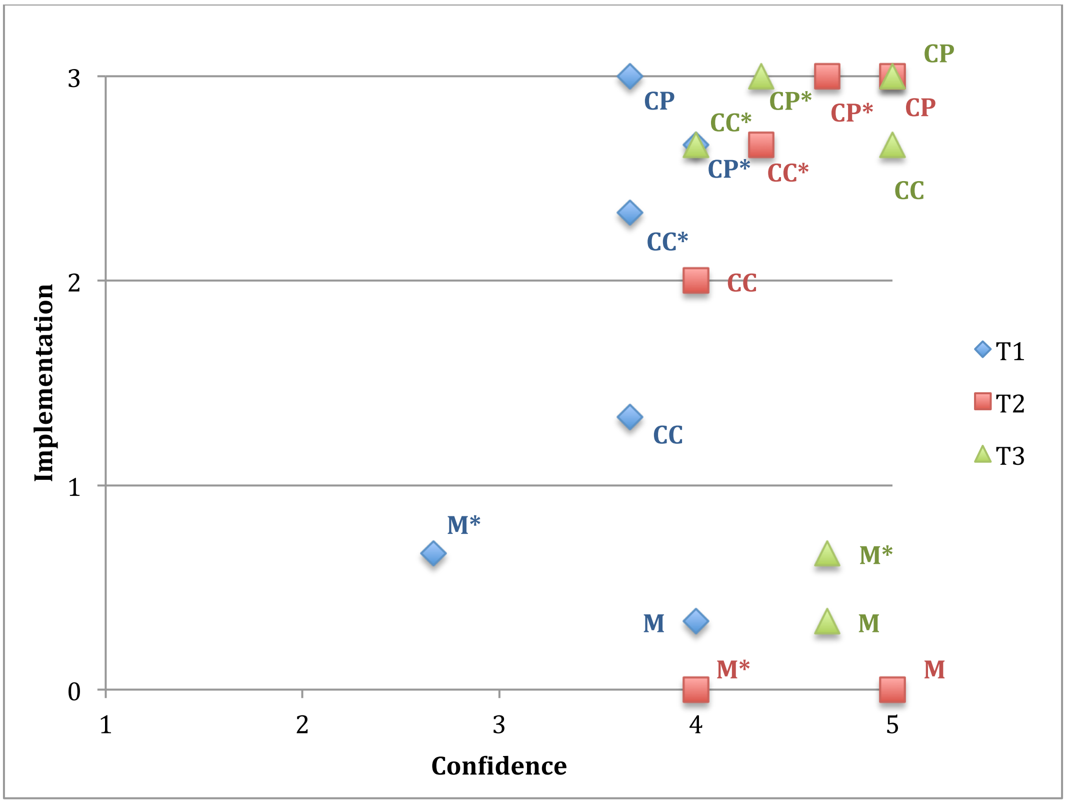

Figure 6.64: Junior Infant teachers' implementation versus confidence for each pillar. Notation described in Table 6.7.

6.5.4 Junior Infant teachers' confidence in their understanding of the science content in the CASE lessons

The Junior Infant teachers' confidence in their understanding of the science content was compared against their implementation of the lessons, as shown in Figure 6.65. The Junior Infant teachers were generally confident in their understanding of the science content covered in the lessons. T1 was not very confident in her understanding of L4, and T3 was not very confident in her understanding of L5. As with the Senior Infant and 1st class teachers, the lessons implemented by the Junior Infant teachers focus on the schemata of pre-operations and do not explicitly cover any science content. The teachers' lack of confidence in these lessons may be as a result of the teachers' unfamiliarity with the lessons.

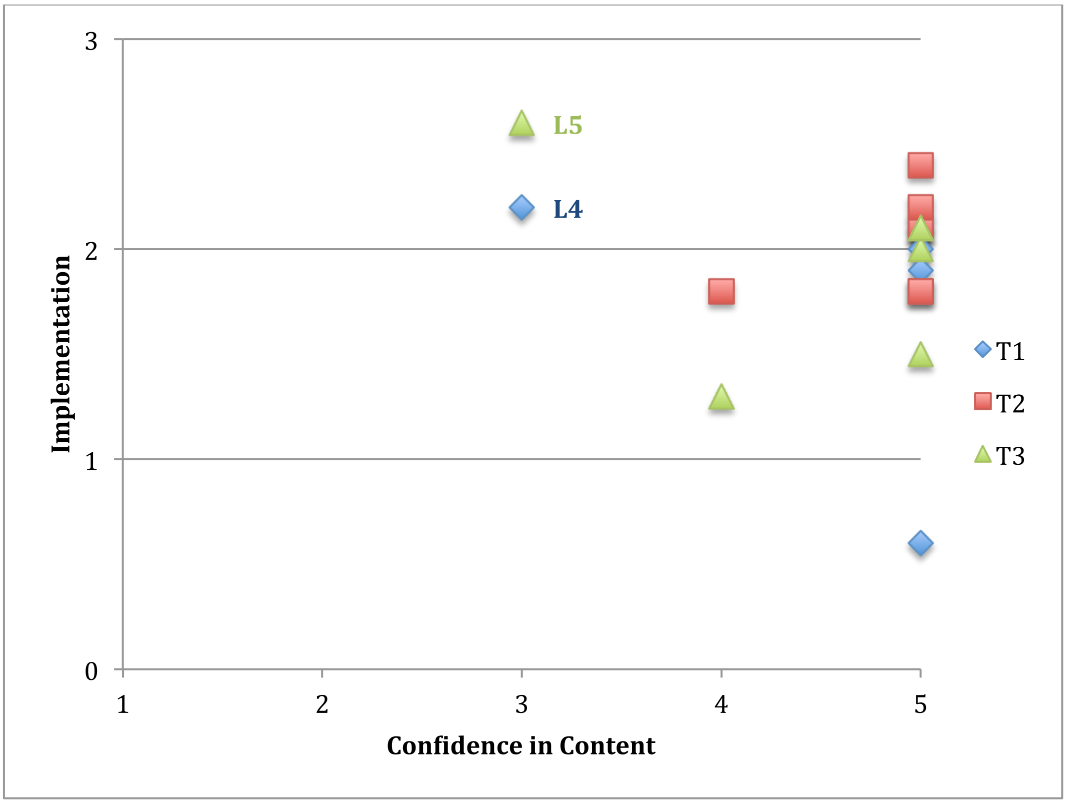

Figure 6.65: Junior Infant teachers' confidence in their understanding of the science content in the lessons versus their implementation

6.5.5 The Junior Infants teachers and the CASE methodology overall

The Junior Infant teachers had a positive attitude towards the CASE methodology and felt that it integrated well with the Junior Infants curriculum, which focuses on encouraging students to work in groups, verbalise their thought processes and to learn to explore and investigate. They also felt that the schemata integrated well with the Maths curriculum. The teachers were confident in their knowledge of the methodology and strategies to implement the lessons successfully at the end of the programme (Q2). The teachers felt that the lessons challenged their students, encouraged them to ask questions and to think for themselves (Q2). The lessons also "*gave the children the opportunity to work together and discuss the topics in more depth*" (T3.Q2). The students enjoyed working in groups as they had the opportunity to speak and be listened to which has encouraged the teachers to try to incorporate collaborative learning into other areas of their teaching (FG3). The teachers saw an improvement in their students' ability to verbalise their thought processes and to think for themselves. In general, the teachers' implementation of the pillars of concrete preparation and cognitive conflict was reasonably successful. Again, the teachers struggled to implement the pillar of metacognition. All three teachers were slightly less confident in their implementation of lesson 5. The lesson reflections indicate that their students found this lesson particularly difficult, which is reflected in the teachers' confidence.

The Junior Infant teachers implemented a total of 6 lessons each. The lessons were carried out with small groups of students on different days, as described in Chapter 3. However, in FG3, the teachers felt that this method was too time consuming than that it would not be feasible to implement the lessons in this manner next year. The teachers felt that they would be able to implement more of the lessons if they were conducted as whole-class activities. It was suggested to the teachers that they implement the lessons together with a learning support teacher to ensure that the students are engaged with the lessons in so far as possible.

The analysis thus far has described the teachers' implementation regarding the pillars of concrete preparation, cognitive conflict, social construction and metacognition. The teachers' ability to relate the thinking within a CASE lesson to other areas is discussed in the next section.

6.6 Bridging

The final pillar of the CASE methodology involves generalizing the thinking the students engaged in during the activity to other areas of learning. The process of bridging is essential to reinforce the students' thinking, and to understand the relevance of what they have learned. Bridging is related to the concept of metacognition in that, to bridge their thinking, the students must first be conscious of it (Adey & Shayer, 1994). In the lesson reflections, the teachers were asked to describe how they were able to bridge the thinking involved in the CASE lessons to other areas of student learning. However, there was no corresponding question that asked teachers to rate their confidence in their ability to bridge the thinking.

The teachers' responses were scaled as described in Section 4.1. A responses was assigned a '1' if the teacher related the science content within the lesson to other curriculum areas, while a '3' was assigned if the teacher related the students' thinking to other learning situations. The teachers' responses were analysed using MDS and the ZAP constructed, as described in Section 6.1.4. The teachers' proximity to the hypothetical ideal is shown in Figure 6.66.

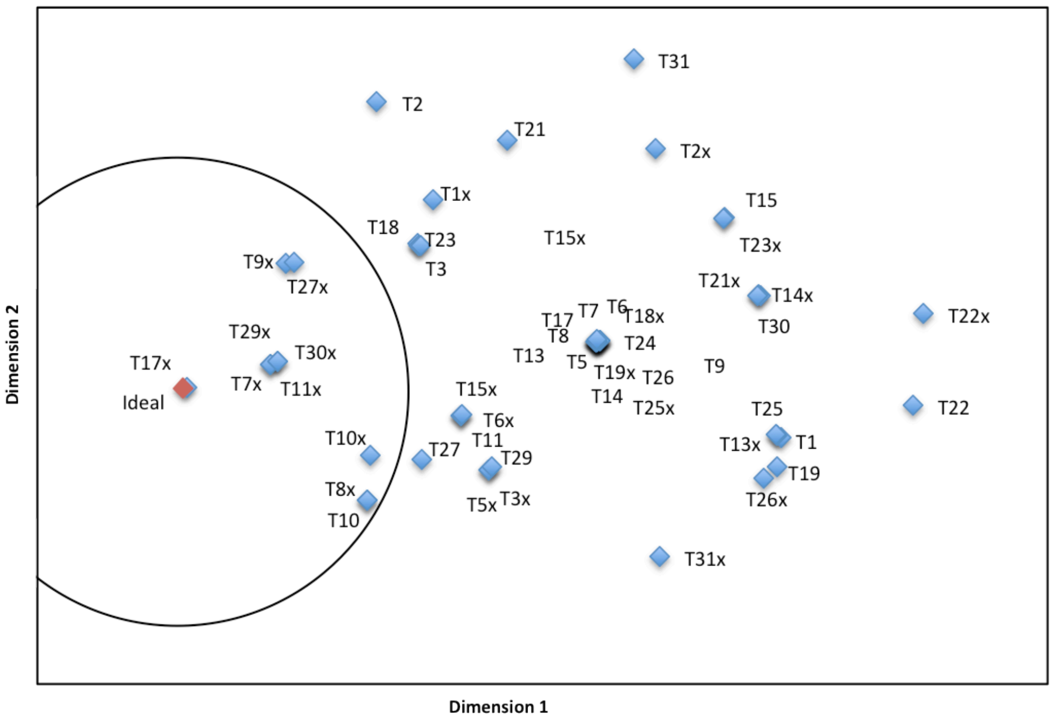

Figure 6.66: Teachers' proximity to the hypothetical ideal teacher in relation to their ability to bridge the thinking from a CASE lesson to other areas of learning.

Again, the teachers were classified according to their overall movement in relation to the ZAP, as shown in Table 6.36. T10 is situated within the ZAP throughout the programme however, the teacher is situated at the perimeter indicating that she was not consistent in their ability to bridge the thinking involved. Seven teachers (T7, T8, T9, T17, T27, T29, T30) improved in their ability to generalize the students' thinking, and are situated within the ZAP at the end of the programme. T17 is situated at the ideal at the end of the third term, indicating that this teacher consistently related the students' thinking to other areas of learning. The remaining teachers are situated outside the ZAP throughout the programme, signifying that these teachers either bridged the scientific content covered in the lessons or left this item blank. A number of teachers from a cluster outside the ZAP, and are represented by the same point on the configuration. These teachers consistently bridged the science content covered in the lesson rather than the students' thinking.

Table 6.36: The teachers' position on the configuration in relation to their ability to bridge the thinking within a CASE lesson to other areas.

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T10
2	Outside ZAP	Inside ZAP	T7, T8, T9, T17, T27, T29, T30
3	Outside ZAP	Outside ZAP	T1, T2, T3, T5, T6, T11, T13,T14, T15, T18, T19, T212, T22, T23, T24, T25, T26, T31
4	Inside ZAP	Outside ZAP	

Although the teachers' ability to generalize the students' thinking varied, there does appear to be a trend between the class groups. Four out of the seven Senior Infant/1st class teachers were situated within the ZAP at the end of the programme (T7, T8, T9, T10). The lessons implemented by the Senior Infant and 1st class teachers, focused heavily on the schema involved and did not explicitly cover any scientific content. The schemata were generally obvious within these lessons, which may make it easier to generalize. Three of the 5th and 6th class teachers were also situated within the ZAP at the end of the programme. While T27 was generally able to bridge the thinking covered within a CASE lesson, T29 and T30 were only able to bridge the schema when there is a direct link with the mathematics curriculum. For example, the last lessons implemented by the 6th class group focus on ratio and proportions and probability, which have obvious, direct links to mathematics, and may explain why these teachers are situated within the ZAP.

None of the teachers of 2nd, 3rd or 4th class were situated within the ZAP at the end of term three (excluding T17). The lessons implemented by these teachers had an increased focus on scientific content, which may explain why the teachers of these class levels consistently related the scientific content covered in the CASE lessons to other curriculum areas, rather than the schema. T17 was the only teacher who consistently related the thinking the students engaged in in the CASE lessons to other contexts. T17 is situated at the ideal in relation to both her ability to engage her students in metacognitive thinking, and to relate their thinking to other areas of learning. This suggests that in order for a teacher to generalize the thinking learned within a CASE lesson, it must first be made explicit. The remaining teachers were unsuccessful in their implementation of the pillar of metacognition and also failed to relate this thinking to other areas of student learning. This finding supports the notion that bringing students thinking into consciousness is an essential aspect of the CASE methodology.

6.7 Conclusions

This section presents the main findings of the analysis of the teachers' responses to the lesson reflections. This analysis highlighted that, in general, all of the teachers in the study improved in their implementation of the CASE lessons from the beginning of the programme. An overview of the teachers' confidence and implementation is shown in Figure 6.67. Twenty of the twenty-six teachers were largely successful in their implementation at the end of the year. The remaining six teachers also improved in their implementation, although these teachers could progress further. T23 was the only teacher who appeared not to have improved in her implementation of the CASE lessons throughout the programme. However, analysis of the teacher's implementation of each pillar of the lesson (Figure 6.17) highlighted that the teacher's implementation of the pillars of concrete preparation and cognitive conflict, were reasonably successful at the end of the programme, and that it was the teachers' implementation of the pillar of metacognition that decreased throughout the year. The pillar of metacognition proved to be the most difficult aspect of the lessons for the teachers to implement and, at the end of the programme, only three teachers (T10, T17 and T27) were somewhat successful in eliciting metacognitive thinking from their students. This analysis highlights that the teachers in this study need further support in relation to this aspect of the lessons. Adey (Adey *et al.*, 2004) notes that it is generally not until the second year of the professional development programme that teachers are able to engage their students in metacognitive thinking, which he proposes is due to a lack of understanding of the concept. The teachers' implementation of this pillar and understanding of the concept of metacognition is explored in detail in Chapter 7.

Implementation \ Confidence	1	2	3	4
1	T2, T5, T7, T8, T11, T17	T6, T25	T10, T27	
2	T3, T14, T19	T21	T1, T9, T15, T18, T26, T30	
3	T24, T29, T31		T13, T22	
4				T23

Figure 6.67: Overall classification of teachers in relation to their confidence and implementation of the CASE lessons throughout the programme.

All of the teachers were successful in their implementation of the pillar of concrete preparation, and the majority of teachers were successful in their ability to guide their students through the cognitive conflict at the end of the programme. Only three teachers (T13, T29 and T31) were not entirely successful in their implementation of the pillar of cognitive conflict at the end of the year. However, researcher observations for T13 and T31 indicate that their implementation of this pillar was more successful than suggested by their responses to the lesson reflections. T13 and T31 left portions of the lesson reflections blank towards the end of the year, which led to slightly unreliable results for these teachers. Researcher observations for these teachers indicate that their implementation was more successful than suggested by their responses to the lesson reflections.

The teachers' confidence in their understanding of the science content does not appear to have been a factor in their implementation of the lessons at any class level. However, as previously mentioned, this is the teacher's self-rating of their knowledge of the scientific content in the lessons and not an actual measure of their scientific understanding. The teachers of Junior Infants to 1st class were generally more successful in their implementation of the lessons, and researcher's observations indicate that teachers of 3rd to 6th class would benefit from additional scientific content knowledge.

A surprising outcome of this analysis also shows that, out of the six teachers who were not entirely successful in their implementation of the lessons at the end of the year, two of these teachers, T24 and T29 participated in the pilot study. Researcher observations for T24 and T29 indicate that they were generally unsuccessful in their implementation of the pillar of cognitive conflict, often revealing the end-point of the lesson to their students, preventing them from engaging in any meaningful thinking. The teachers were also unsuccessful in their ability to elicit metacognitive thinking from their students. This mirrors the teachers' implementation of the lessons during the pilot study, indicating that the teachers made very little progress in their ability to implement the lessons over the two years. T24 and T29 are situated in Group C in Figure 6.67 indicating that the teachers were generally confident despite being largely unsuccessful in their implementation of the lessons. This suggests that these teachers may not fully understand the CASE methodology and require further support to improve their implementation of the lessons. Of the remaining two teachers who participated in the pilot study, T2 (Junior Infants) was successful in her implementation throughout the programme and T12 (1st class) did not return a sufficient number of lesson reflections to be considered in this analysis.

The teachers' confidence in their implementation varied, and eleven of the teachers were not very confident in their implementation of the lessons at the end of the programme. Analysis of the teachers' implementation of each pillar of the lesson highlights that this lack of confidence primarily concerns the teachers' implementation of the pillar of metacognition and that the teachers were generally more confident in their implementation of the pillars of concrete preparation and cognitive conflict.

Overall, the teachers had a positive attitude towards the CASE methodology. The teachers felt that the lessons integrated well with the Irish primary science curriculum in relation to developing students' scientific skills. The teachers observed improvements in their students' ability to think for themselves, provide valid explanations for their answers and work collaboratively. The teachers generally improved in their implementation of the lessons. Adey (*Adey et al.,* 2004) noted that it is not usually until the second year of professional development that teachers are able to assimilate their pedagogies into their classroom practices. This analysis highlights that after a period of one year almost all of the teachers had improved in their ability to guide their students through the cognitive challenge and facilitate classroom discussions. The teachers focused less on the science content in the lessons, and began to challenge the students thinking. The teachers felt that this was as a result of their improved questioning skills and familiarity with the methodology. A number of teachers were not very confident in their understanding of the methodology at the end of the programme, however all of the teachers feel that the lessons will be easier to teach next year. This analysis indicates that the teachers require further support in their understanding of the CASE methodology particularly concerning their knowledge and pedagogies relating to the concept of metacognition. The teachers' implementation and understanding of metacognition is discussed in more detail in the next chapter.

Chapter 7

The Teachers' understanding of Metacognition

Introduction

The analysis described in Chapter 6 highlighted that the teachers were unable to engage their students in metacognitive thinking throughout the programme. This chapter aims to provide a deeper insight into the teachers' understanding of the concept of metacognition. The chapter is divided into three sections. Section 7.1 provides a brief overview of the concept of metacognition in relation to the CASE methodology. Section 7.2 analyses the teachers' responses to the lesson reflections to gain a deeper insight into the strategies employed during the metacognitive phase of the lessons. The researcher's observations are considered to further inform this analysis. Section 7.3 discusses the analysis of a questionnaire completed by the teachers following the implementation phase of the study, which sought to establish their understanding of the concept of metacognition. Finally, Section 7.4 discusses a possible approach to develop teachers' pedagogical skills in the context of metacognition.

7.1 Metacognition and CASE

Before discussing the results of this study, it is necessary to clarify what is meant by the term metacognition in general, and in relation to the CASE methodology, specifically. The term metacognition was first introduced by Flavell (1979), and refers to becoming conscious of one's own thinking and reasoning. However, the notion of conscious attention to ones' thinking is not a new concept and has been recognised as far back as Plato and Aristotle (Spearman, 1923 cited in Georghiades, 2004). Piaget (1976) and Vygotsky (1986) noted the importance of awareness of thinking in cognitive development, as thinking processes can only be controlled when they have been brought into consciousness. Zohar and Barzilai (2013) highlight a lack of coherence within the literature regarding the definition of metacognition, although there is a general consensus that metacognition involves both metacognitive knowledge and metacognitive skills. Metacognitive knowledge refers to knowledge about oneself as a learner, and knowledge about tasks and strategies. Metacognitive skills refer to the ability to plan, monitor and evaluate ones thinking processes (Ben-David & Orion, 2012; Zohar and Barzilai, 2013).

The role of metacognition in teaching has become a prominent issue in educational research in recent years, due to its potential to improve student learning outcomes (Zohar & Barzilai, 2013). Improved metacognitive knowledge and skills have shown to have positive effects on a range of learning capabilities including problem-solving abilities (Zohar & David, 2008), reading comprehension (Haller, *et al*., 1988) and scientific understanding (Zohar & Peled, 2008). Metacognition is also considered important in the development of thinking skills, and is a feature of both Feuerstein's Instrumental Enrichment and Lipman's Philosophy for Children programmes discussed in Chapter 2.

In relation to the CASE methodology, Adey and Shayer (1994) distinguish between self-regulation and conscious attention to one's own thinking, which they refer to as 'going beyond' and 'going above' respectively. According to Adey (2004), 'going beyond' is "the process of pushing one's thinking on further than usual, of stretching ones capabilities as a result of cognitive conflict and social construction" (Adey, 2004 p. 311). During this phase of the lesson, the students are encouraged to use their metacognitive knowledge and display executive control; however, this is usually an unconscious process, and the thinking employed remains implicit. The metacognition phase within a CASE lesson generally refers to 'going above', which is also known as metacognitive reflection. According to Georghiades;

> *Metacognitive reflection involves the critical revisiting of the learning process in the sense of noting important points of the procedures followed, acknowledging mistakes made on the way, identifying relationships and tracing connections between initial understanding and learning outcomes.*
> (Georghiades, 2004 p. 317).

'Going above' involves consciousness, reflective awareness about strategies, and thinking about thinking. Adey and Shayer (1994) highlight that both 'going beyond' and 'going above' are necessary to reach a higher level of understanding, and that 'going beyond' is a prerequisite for 'going above'. A student cannot reflect on, and evaluate their thinking if they did not engage in challenging tasks to extend their cognitive abilities. While the process of 'going beyond' is necessary to 'go above', the contrary does not necessarily apply. However, Adey and Shayer consider metacognitive reflection as an essential aspect of the CASE methodology that must be brought about by the teacher:

> *Children may have been given many and rich opportunities for going-beyond activities but they may not spontaneously proceed to a going-above step, and can very easily lose the bulk of what they have precariously achieved unless a mediator provides them with the time and occasion to abstract as well* (Adey & Shayer, 1994 p.70).

Adey (2004) highlights that metacognitive thinking within a CASE lesson is not restricted to metacognitive reflections after a task. A students' thinking processes can be brought into conscious as they engage in an activity, however, he notes that if the task is sufficiently challenging, the student may not have enough working memory space to do this spontaneously, and it must be brought about by the teacher.

Fischer (1998) refers to 'going beyond' and 'going above' as cognitive extension (CE) and metacognitive thinking (MT). These terms will be used to distinguish between the two levels of thinking in this analysis. Metacognitive thinking within a CASE lesson is also closely related to the process of bridging. The transfer of thinking to unrelated contexts and situations is more likely to be successful if the student is conscious of their new thinking, and it has been verbalized (Adey & Shayer, 1994). The next section analyses the teachers' responses to the lesson reflections and discusses their ability to engage their students in metacognitive thinking, as described by Adey and Shayer (1994).

7.2 The teachers' responses to the lesson reflections

The teachers' responses to the lesson reflections were analysed first using MDS to provide an overview of the teachers' implementation of the pillar of metacognition throughout the programme. The strategies employed by each teacher to elicit metacognitive thinking were then analysed in more detail. This analysis is then informed by the researcher's observations for the teachers of 2nd – 6th class.

7.2.1 Multidimensional Scaling Analysis

In order to analyse the teachers' overall change in confidence and implementation of the pillar of metacognition, their responses to the lesson reflections were analysed using MDS, as described in Section 6.1.4. Figure 7.1, Table 7.1 and Table 7.2 summarise the teachers' change in implementation with regard to the ZAP, and Figure 7.2, Table 7.3 and Table 7.4 summarise the teachers' change in confidence in a similar manner.

a) Implementation

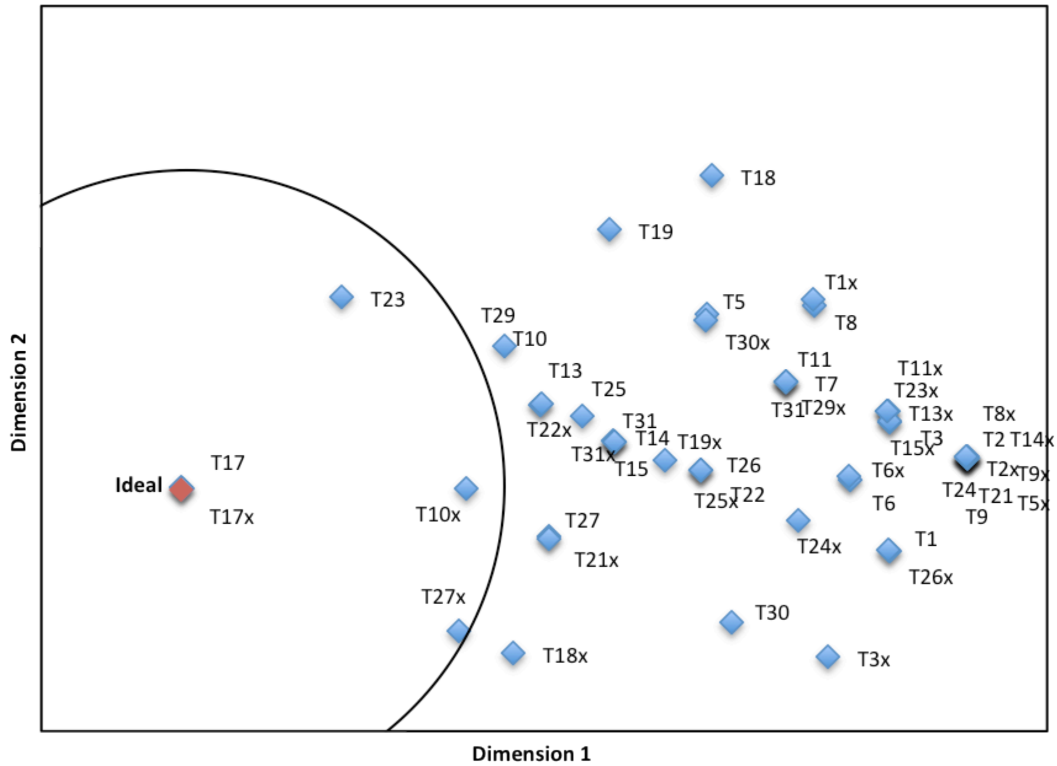

Figure 7.1: The teachers' proximity to the hypothetical ideal teacher in relation to their implementation of the pillar of metacognition.

Table 7.1: Teachers' implementation of the pillar of metacognition from term one to term three with regard to the ZAP

Implementation	
Term 1	**Term 3**
• T17 and T23 are situated within the ZAP • T17 is situated at the 'Ideal' • The reaming teachers are situated outside the ZAP	• T17 remains within the ZAP and is situated at the ideal • T10 and T27 move into the ZAP • T12, T21 and T22 move towards the ideal, but are situated just outside the ZAP • The reaming teachers do not move towards the 'Ideal' and remain situated outside the ZAP

The teachers were classified according to their overall change in implementation from the beginning of term one, to the end of term three, as shown in Table 7.2. The majority of teachers are in Group 3, indicating that their implementation of this pillar was unsuccessful throughout the programme.

Table 7.2: Classification of the teachers in relation to their implementation of the pillar of metacognition from term one to term three

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T17
2	Outside ZAP	Inside ZAP	T10, T27
3	Outside ZAP	Outside ZAP	T1, T2, T3, T5, T6, T7, T8, T9, T11, T13, T14, T15, T18, T19, T21, T22, T24, T25, T27, T29, T30, T31
4	Inside ZAP	Outside ZAP	T23

b) Confidence

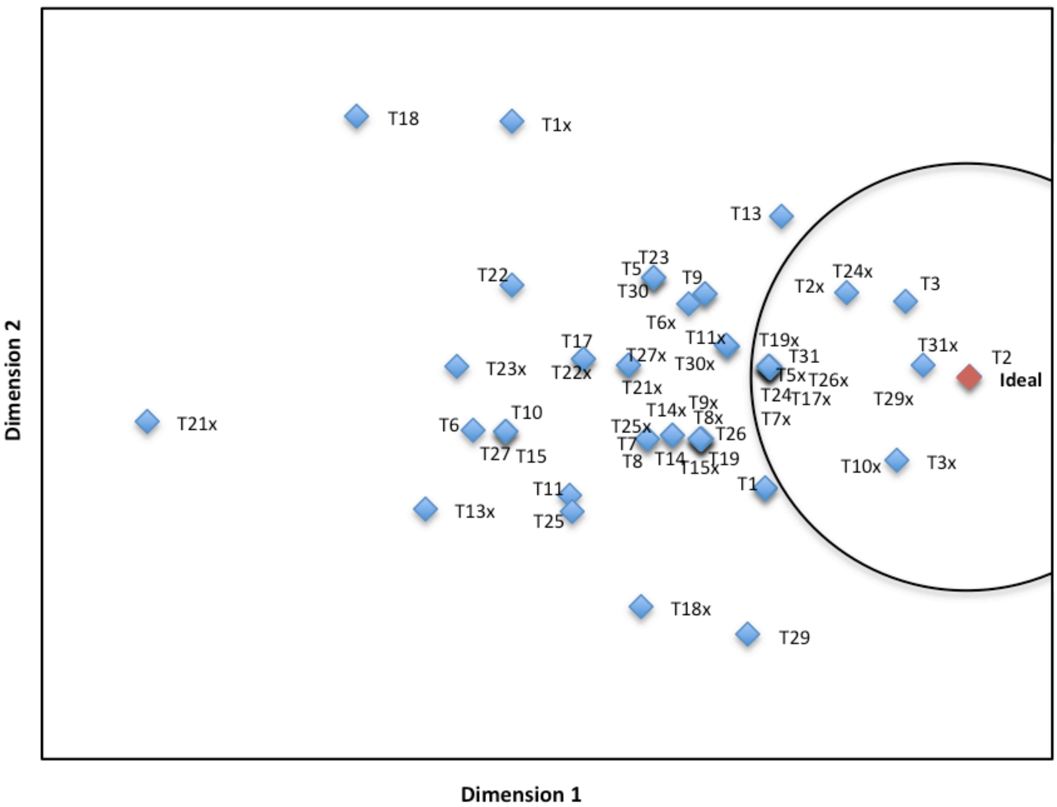

Figure 7.2: The teachers' proximity to the hypothetical ideal teacher in relation to their confidence. Note: Multiple teachers are represented by the same point on the configuration.

Table 7.3: Teachers' confidence in relation of the pillar of metacognition from term one to term three with regard to the ZAP

Confidence	
Term 1	**Term 3**
• T17 and T23 are situated within the ZAP • T17 is situated at the 'ideal' • The reaming teachers are situated outside the ZAP	• T17 remains within the ZAP and is situated at the ideal • T10 and T27 move into the ZAP • The reaming teachers remain situated outside the ZAP

The teachers were classified according to their overall movement in relation to their change in confidence from the beginning of term one to the end of term three, as shown in Table 7.4. Again, the majority of teachers are in Group 3, indicating that they were not very confident in their implementation of this pillar throughout the programme.

Table 7.4: Classification of the teachers in relation to their confidence regarding the pillar of metacognition from term one to term three

	Term 1	Term 3	Teachers
1	Inside ZAP	Inside ZAP	T2, T3, T24, T29, T31
2	Outside ZAP	Inside ZAP	T5, T7, T10, T17, T19 T26
3	Outside ZAP	Outside ZAP	T1, T6, T8, T9, T11, T13, T14, T15, T18, T21, T22, T23, T25, T27, T30
4	Inside ZAP	Outside ZAP	

A matrix was created, comparing the teachers' overall change in implementation (Table 7.3) and confidence (Table 7.4) regarding the pillar of metacognition from term one to term three, as shown in Figure 7.3.

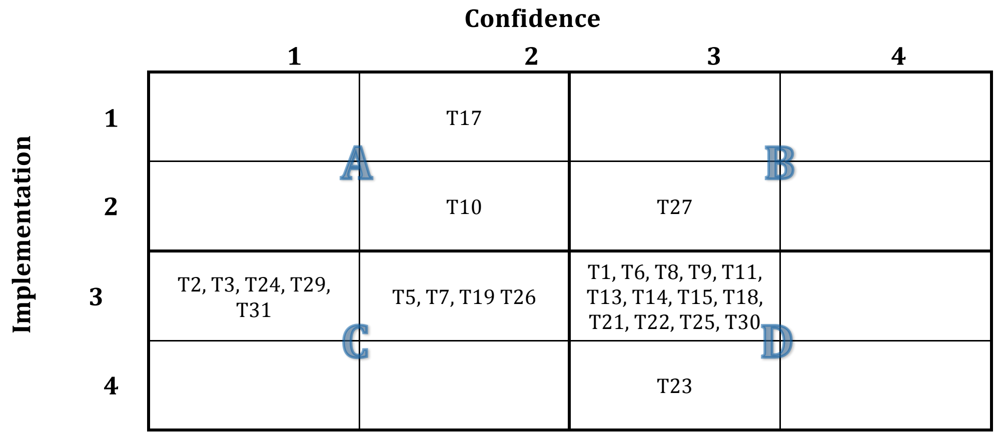

Figure 7.3: Classification of the teachers in relation to their implementation and confidence in implementing the pillar of metacognition (1=good, 4=poor)

This analysis highlights that only 3 teachers (T17, T10, T27) were successful in their implementation of the pillar of metacognition at the end of the year. T17 and T10 were confident in their implementation, however T27 was less confident. T17 is situated at the ideal and is the only teacher who is consistently successful in her implementation. While T10 and T27 were situated within the ZAP in relation to their implementation at the end of term three, they were situated at the perimeter, which signifies that their responses to the lesson reflections were generally assigned a 2. When rating the teachers' responses, as described in Chapter 4, a rating of 2 indicated that the teacher encouraged their students to recap on *what* they did during the lesson, rather than encouraging them to describe their thinking process. Therefore, while both teachers are situated within the ZAP, they could improve further in relation to their implementation. At the beginning of term one, T23 also encouraged her students to reflect on what they did during the lesson, and was therefore situated at the outskirts of the ZAP. However, towards the end of the year, the teacher often left this item in the lesson reflection blank, or responded that the metacognition phase was unsuccessful, and therefore moved out of the ZAP.

The remaining teachers were largely unsuccessful in their ability to generate metacognitive thinking throughout the programme. Figure 7.3 highlights that ten of the teachers were confident in their implementation of the pillar of metacognition despite being unsuccessful in their implementation. The strategies employed by the teachers to elicit metacognitive thinking from their students are discussed in the next section.

7.2.2 Strategies employed to elicit metacognitive thinking

Item 15 in the written lesson reflections required the teachers to describe the strategies they employed to elicit metacognitive thinking from their students. The analysis highlighted that there were three distinct categories of responses to this item:

i. Questions that encouraged the students to reflect on their thinking processes (high-level reflections),
ii. Questions that encouraged the students to reflect on what they did (low-level reflections),
iii. Questions that challenged the students' thinking during the lesson (cognitive extension)

In their description of metacognition, Adey and Shayer (1994) distinguish between 'low-level' and 'high-level' reflections, as discussed by von Wright (1992). According to von Wright, a learner at the lower level is:

> *capable of reflecting about many features of the world in the sense of considering and comparing them in her mind, and of reflecting upon her means of coping in familiar contexts. However . . . she is unlikely to be capable of reflecting about herself as the intentional subject of her own actions. (Von Wright 1992: 60–61).*

At the higher level, however, he says that:

> *Reflecting about one's own knowledge or intentions involves an element which is absent from reflections about the surrounding world. Self-reflection presupposes, in the language of mental models, a 'metamodel': in order to reason about how I reason, I need access to a model of my reasoning performance. (Von Wright 1992: 61)*

Higher-level reflections, as described above, equate with Adey and Shayer's (1994) definition of metacognition in relation to the CASE methodology i.e. metacognitive thinking (MT). High-level reflections involve students reflecting on their performance and evaluating their thinking, while low-level reflections involve students reflecting on what they did. A third category of response was identified, which did not encourage any form of reflection. These questions encouraged the students to extend their capabilities during the cognitive conflict/social construction aspect of the lesson (CE), and while this is good practice to guide the students through the task, it does not provoke the students to reflect on their thinking in any way. Using this distinction, the teachers' responses were classified according to the level of reflection they encouraged the students to engage in (summarized in Table 7.5). As the teachers' ability to elicit metacognitive thinking varied throughout the year, typically only the last three lessons implemented by each teacher were considered as an indication of their implementation of this pillar at the end of the programme. Four teachers were classified as 'undetermined' as they often left this item on the lesson reflection blank, or they responded that they followed the questions supplied in the lesson plan.

Table 7.5: Categorisation of teachers' responses to item 15 in the lesson reflection

	Level of Reflection	**Description**	**Teacher**
i)	High	Questions that encourage the students to reflect on their thinking (MT)	T17
ii)	Low	Questions that encourage the students to reflect on what they did	T1, T2, **T10,** T21, T18, T19, T22, **T23, T27**, T29, T30, T31
iii)	No Reflection	Questions that challenge the student thinking during the lesson (CE)	T3, T5, T6, T7, T8, T11, T13, T24, T26
iv)	Undetermined	Teacher responded that they "Followed the lesson plan" or the item left blank	T9, T14, T15, T25

The teachers' responses to the lesson reflections suggest that only one teacher, T17, encouraged high-level reflection (MT) in her students. While a significant number of teachers encouraged their students to reflect, this was at a low level and usually involved asking the students to recap on what they did during the task, and the conclusions they reached. T10 and T27, who were situated at the boundary of the ZAP in in relation to their implementation at the end of the year (Figure 7.1), also encouraged low-level reflections. Nine of the teachers did not encourage their students to reflect in any way. These teachers responded to the lesson reflections with questions/strategies that encouraged CE, suggesting that they do not fully understand the concept of metacognition. The analysis of the teachers' implementation of the pillar of metacognition has been based upon the teachers' responses to the lesson reflections, thus far. Researcher observations for the teachers of 2nd to 6th class are now considered to analyse the validity of this analysis.

7.2.3 Researcher Observations

The teachers of 2nd – 6th class were observed implementing the CASE lessons between three and seven occasions. As discussed in Chapter 4, an observation scale was used to rate the teachers' success in implementing the different aspects of the lesson, including their ability to generate metacognitive thinking. The metacognition phase was rated according to the rubric shown in Table 7.7.

The teachers of Junior Infants, Senior Infants and 1st class were not observed teaching the CASE lessons on a regular basis and could not be considered as part of this analysis. T25 was not observed on any occasion during the programme and was also not included in this analysis. The observation rating assigned to each teacher for their implementation of the pillar of metacognition is shown in Table 7.6.

Table 7.6: 2nd – 6th class teachers' observation rating for the pillar of metacognition (Ob = observation; Rating as described in Table 7.7)

	Ob1	Ob2	Ob3	Ob4	Ob5	Ob6	Ob7	Overall
T13	3	3	**3**	**3**				3
T14	3	4	4					4
T15	3	4	**4**	**4**				4
T17	4	4	4	**5**	**5**	**5**		5
T18	2	3	3	**4**	**2**	**3**		3*
T19	3	3	**4**	**4**	**4**			4
T21	4	3	3	**4**	**4**	**4**		4
T22	3	3	3	**3**				3
T23	4	3	**3**	**3**				3
T24	3	3	**3**	**3**				3
T25	-	-	-	-	-	-	-	-
T26	3	3	3	**3**	**4**	**3**		3
T27	4	3	4	**4**	**4**	**4**	**4**	4
T29	1	1	2	2	**2**	**2**	**2**	2
T30	3	3	3	**3**	**3**			3
T31	3	3	3	3	**3**	**3**		3

As the teachers' ability to generate metacognitive thinking varied throughout the year, the observation ratings towards the end of the programme (term three) were used as an indicator of their ability to implement this pillar. These observation ratings are shown in bold in Table 7.6. For the last three lessons implemented, T18 ranged from a 2 to a 4, indicating that in in some lessons the teacher asked questions asking her students to reflect on what they did while in others she was somewhat able to engage her students in metacognitive discussions. For the purpose of this analysis, the teacher was assigned a 3, although her implementation of this pillar varied.

It should also be noted that T14 was not observed implementing the lessons towards the end of the programme, and the observation ratings for this teacher correspond to lessons 2, 3 and 4. T23 was only observed on one occasion in the third term (L11). The teachers were classified in relation to their general success in implementing the pillar of metacognition according to the researchers' observations, as shown in Table 7.7.

Table 7.7: Description of teachers' implementation of the pillar of metacognition according to the researchers' observations.

Rating	Description	Teachers
5	Teacher was able to generate a reflective discussion where students articulated and evaluated their thinking	T17
4	Teacher read the questions supplied in lesson plan and was able to expand on this, generating some reflective discussion on the students' thinking	T14, T15, T19, T21, T27
3	Teacher read the questions supplied in the lesson plan but was not able engage with students' responses	T13, T18, T22, T23, T24, T26, T30, T31
2	Teacher asked questions reflecting on what the students did rather than focusing on the thinking they engaged in	T29
1	The teacher omitted the metacognition aspect of the lesson	

In general, the teachers' responses to lesson reflections do not completely agree with the researchers' observations. In order to compare the teachers' implementation of the pillar of metacognition as suggested by their lesson reflections, and their implementation as suggested by the researchers' observations, a matrix comparing the two scales was created as shown in Figure 7.4.

Researcher Observations

Lesson Reflections	5	4	3	2	1
High	T17				
Low		T21, T27, T19	T22, T23, T30, T31	T29	
No Reflection			T13, T24, T26		
Undetermined		T14, T15			

Figure 7.4: Teachers' responses to the lesson reflections versus the researcher observations for their implementation of the pillar of metacognition

A description of the teachers' lesson reflection responses versus the researcher observations is shown in Table 7.8.

Table 7.8: Description of the teachers' responses to the lesson reflections versus the researcher observations for their implementation of the pillar of metacognition

Level of Reflection	Teachers	Description
High-level Reflection	T17	Teacher's responses in lesson reflections encourage high-level, metacognitive reflections and researcher's observations indicate that she was able to generate metacognitive thinking in her students.
Low-level Reflection	T21, T27, T19	Teachers' responses in the lesson reflections encourage low level reflections however, researcher observations suggest that these teachers asked the questions suggested in the lesson plan, and were able to generate some metacognitive discussion
	T22, T23, T30, T31	Teachers' responded to the lesson reflections with questions to encourage low-level reflections however, researcher observations suggest that these teachers asked the questions in the lesson plan, although they were not able to elicit much metacognitive thinking
	T29	The teacher responded to the lesson reflections with questions to encourage low-level reflections, which generally agreed with the researchers' observations for this teacher
No Reflection	T13, T24, T26	Teachers responded to the lesson reflections with questions to encourage CE, rather than encouraging the students to reflect on any part of the lesson. However, researcher observations suggest that these teachers generally followed the questions suggested in the lesson plan, although they were not able to generate much metacognitive thinking in their students.
Undetermined	T14, T15	Teachers' implementation of the metacognition phase was undetermined using their lesson reflection responses, however, researcher observations indicated that T14 and T15 were able to generate some metacognitive discussion beyond reading the questions supplied in the lesson plan.

The researcher observations suggest that, in general, the teachers of 2nd to 6th class followed the questions supplied in the lesson plan for the metacognition phase of the lesson. The teachers' ability to elicit metacognitive thinking varied, with six of the fourteen teachers (T14, T15, T17, T18, T21, T27) able to engage their students in metacognitive discussions. However, when describing the questions they asked to elicit metacognitive thinking in the lesson reflections, the majority of the teachers responded with questions that challenge the students thinking during the cognitive conflict/social discussion phase of the lesson (CE). This suggested that these teachers did not fully understand the concept of metacognition. The teachers' understanding of the concept of metacognition is discussed in more detail the next section.

7.3 The teacher's understanding of metacognition

The analysis of the teachers' implementation of the CASE lessons highlights that the majority of teachers were unable to elicit metacognitive thinking from their students or engage them in metacognitive discussions. To gain a deeper insight into the teacher's understanding of the concept of metacognition, the teachers were administered a questionnaire (Q3) following the implementation phase of the study, in December 2013. The questionnaire sought to establish:

- whether the teachers could distinguish between CE and MT;
- whether the teachers referred to conscious awareness of thinking;
- their confidence in their ability to elicit metacognitive thinking;
- how important they felt the concept of metacognition is and;
- any supports they felt would help them in their ability to generate metacognitive thinking.

The 5-item questionnaire consisted of open, closed, Likert-scale and tick the box type questions (Appendix H). Twenty-two teachers responded to the questionnaire, however T5, T22, T30 and T31, who participated in the lesson reflection analysis, did not. The analysis of the questionnaire was divided into two sections, discussed below. The first section sought to establish whether the teachers could distinguish between MT and CE, while the second section identified whether the teachers referred to conscious awareness of thought when describing metacognition.

7.3.1 Differentiation between MT and CE

Item 1 on Q3 asked the teachers to identify which of the following situations they felt encouraged metacognitive thinking:

A. *Teacher asking questions during the lesson to challenge the students thinking*
B. *Teacher encouraging students to explain their answers*
C. *Teacher encouraging their students to reflect on what they have learned during the lesson*
D. *Teacher encouraging their students to reflect on the thinking they engaged in during the lesson*
E. *Teacher allowing their students to discuss their ideas with each other*

Option D is the only situation that explicitly encourages students to become aware of their thinking. Therefore, in theory, a teacher who considers any of the other options (A, B, C, E) as a situation that encourages metacognitive thought, suggests that they do not fully understand the concept of metacognition. However, none of the respondents selected only option D. For example, T17, who continuously displays an understanding of the concept of metacognition, and is able to engage her students in metacognitive discussions, also considers options B and C to encourage metacognitive thinking. This may be due to the ambiguous nature of the questions, which are open to misinterpretation by the teachers. It is therefore difficult to completely define the teachers' understanding of metacognition from this question. However, it is possible to determine whether a teacher is able to distinguish between CE and MT. Option A specifically describes a situation that encourages CE during the cognitive conflict/social construction phase of the lesson. Therefore, a teacher who considers Option A as a situation that encourages metacognitive thought indicates that they are unable to distinguish between CE and MT.

The analysis of the teachers' responses to Q3 highlighted that only four teachers (T3, T14, T17, T21) did not consider situation Option A to encourage metacognition, which suggests that only these teachers are able to differentiate between the two levels of thinking. However, T3 also did not consider Option D (*the teacher encouraging their students to reflect on the thinking they engaged in during the lesson*) as a situation that would generate metacognitive thinking, demonstrating that she does not understand the concept of metacognition. The remaining teachers considered all of the options, A-E, to encourage metacognitive thinking, excluding T13 who did not consider Option D as a situation that would generate metacognitive thought. Only three teachers were able to distinguish between CE and MT, as shown in Table 7.9

Table 7.9: Classification of teachers in relation to their ability to distinguish between CE and MT

Description	Teacher
Can distinguish between CE and MT	T14, T17, T21
Unable to distinguish between CE and MT	T1, T2, T3, T6, T7, T8, T9, T10, T11, T13, T15, T18, T19, T23, T24, T25, T26, T27, T29

7.3.2 Consciousness of Thinking

In section 2 of Q3, the teachers were asked to rate how important they considered the concept of metacognition, and to describe why. While all of the teachers rated metacognition as either important or very important, the reasons as to why varied. In interpreting the teachers' responses two categories were identified; responses that referred to bringing thinking into consciousness, and those that did not. Two example responses are highlighted below:

> *It is important because it encourages and promotes learning among not only the children who may be encouraged to explain their answers/reflect on what they have learned but all the children who will be listening also. Promotes children learning from each other. (T8.Q3)*

> *It is important because it encourages the children to think about how they have learned and so they gain the knowledge about when and how to use particular strategies for learning or for problem solving. (T25.Q3)*

T25's response refers to students becoming aware of their thinking so that it can be applied in future learning; however, while T8 refers to students reflecting on what they have learned, this is at a low-level and refers to reflection on answers, rather than on thinking. Only eight of the twenty-two respondents to Q3 referred to students becoming aware of their thinking (T6, T9, T14, T15, T17, T21, T25, T27). The teachers were classified in relation to their ability to both distinguish between CE and MT, and whether they referred to students becoming aware of their own thinking, as shown in Table 7.10.

Table 7.10: Teachers' ability to distinguish between CE and MT and describe metacognition as awareness of thinking

Group	Distinguished between CE and MT	Referred to consciousness of thinking	Teachers
1	✓	✓	T14, T17, T21
2	✗	✓	T6, T9, T15, T25, T27
3	✗	✗	T1, T2, T3, T7 T8, T10, T11, T13, T18, T19, T23, T24, T26, T29

The teachers were grouped according to their responses to Q3 described above. This analysis suggests that only eight teachers recognise that metacognition involves consciousness of thinking, and only three teachers, T14, T17 and T21 (Group 1) are able to distinguish between CE and MT. The remaining fourteen teachers (Group 3) do not appear to understand the concept of metacognition on any level. To analyse whether the teachers' understanding of the concept of metacognition had any effect of their ability to engage their students in metacognitive thinking, the classification of the teachers described in Table 7.10 was compared with the teachers' lesson reflection responses (Table 7.5) and the researcher's observations (Table 7.7), as shown in Figures 7.5 and 7.6 respectively.

Researcher Observations

Understanding of Metacognition	5	4	3	2	1
1	T17	T14, T21			
2		T15, T27			
3		T19	T13, T18, T23, T24, T26	T29	

Figure 7.5: Teachers' understanding of metacognition (Table 7.10) compared with their researcher's observations for their implementation of this pillar (Table 7.7)

Lesson Reflections

Understanding of Metacognition	High-level Reflection	Low-level Reflection	No Reflection	Undetermined
1	T17	T21		T14
2		T6, T27		T9, T15, T25
3		T1, T2, T6, T7, T10, T18, T19, T23, T29	T3, T8, T11, T13, T24, T26	

Figure 7.6: Teachers' understanding of metacognition (Table 7.10) compared with their responses to the lesson reflections (Table 7.5)

The teachers are discussed within the groups described in Table 7.10.

Group 1

The researcher's observations for the teachers in Group 1 agree with the teachers' responses to Questionnaire 3, as shown in Figure 7.5. The teachers appear to understand the concept of metacognition and are reasonably successful in generating metacognitive discussions. T17 is consistently successful in eliciting metacognitive thinking from her students, and asks questions to encourage high-level reflections. T14's responses to the lesson reflections were classified as ‘undetermined’ as shown in Figure 7.6. T14 consistently responded that she ‘follows the lesson plan’, however, the teachers’ responses to Questionnaire 3, and researcher observations, indicate that T14 understands the concept of metacognition and is able to engage her students in metacognitive discussions. In her lesson reflections, T21 tended to ask questions that encouraged low-level reflections. As discussed in Chapter 6, T21 did not consider the lessons challenging enough for her students, and found it difficult to encourage her students to reflect on their thinking processes when they often did not engage in any (Q2).

Group 2

In their responses to Q3, the five teachers in Group 2 recognise that metacognition involves consciousness of thinking, however, they are unable to distinguish between CE and MT. Of the five teachers, three (T9, T15, T25) were classified as ‘undetermined’ according to their lesson reflection responses as they often left this item blank. However, the teachers’ responses to Q3 suggest that they have some understanding of the concept of metacognition. This agrees with researcher observations for T15, who focused on the students’ thinking during lessons, and was able to generate some metacognitive discussion. T9 and T25 were not observed implementing the CASE lessons and therefore, there is no observation data to support the teachers’ responses to Q3. T6 and T27’s responses to the lesson reflections tended to focus on low level reflections, however, the teachers’ responses to Q3 suggest that they have some understanding of the concept. T27 was inconsistent in her responses to lesson reflections. This agrees with researcher observations for this teacher, as she tended to ask questions to encourage high-level reflection in some lessons, and low-level reflections in others. This may be as a result of the teachers’ inability to differentiate between CE and MT, and indicates that she does not fully understand the concept of metacognition. T6 was not observed teaching the CASE lessons and again there is no observation data to support the teachers’ responses to Q3.

Group 3

The remaining teachers’ responses to Q3 suggest that they do not understand the concept of metacognition. This agrees with their responses to the lesson reflections, as they either ask questions to encourage low-level reflection or CE. This also agrees with the researcher's observations for T13, T23, T24, T26 and T29, which indicate that the teachers were unable to engage their students in metacognitive discussions. These teachers also tended to focus more on the science content covered in the lesson, rather than the students' thinking. Researcher observations for T19 do not completely agree with the teachers' classification according to Q3. During CASE lessons, this teacher focused on the students' thinking and often asked questions to encourage his students to think about their thinking, although, his responses to the lesson reflections and Q3 suggest that he does not fully understand the concept. However, the analysis described in Section 6.1.7. indicates that T19's implementation is generally more successful than suggested by his responses to the written lesson reflections.

There are limitations to this analysis in that teacher responses to Q3 were open to interpretation by the researcher. So as not to misconstrue the teachers' responses, a teacher was only classified as '*referred to consciousness of thinking'* if it was explicitly mentioned in their response. To verify the classification of the teachers, as shown in Table 7.10, the teachers' responses to Q3 were analysed by two independent researchers. The researchers were asked to consider whether the teachers' responses demonstrated that the teacher associated metacognitive thinking with consciousness of thought. The results of this analysis agreed with the classification shown in Table 7.10. A second limitation of this analysis involves using the teachers' responses to the lesson reflections to evaluate their implementation of the pillar of metacognition. Analysis of the teachers of 2nd – 6th class indicates that the researchers' observations for these teachers were a more accurate indication of their success in engaging their students in metacognitive discussions. However, the teachers of Junior Infants, Senior Infants and 1st class did not participate in regular observations and, as a result, there are no researcher observations to support/dispute their implementation of the pillar of metacognition as suggested by their lesson reflection responses. However, the teachers' responses to Q3 indicate that they do not understand the concept of metacognition.

7.4 Conclusions

Metacognition has previously been highlighted as one of the more difficult tasks for cognitive acceleration teachers (Adey *et al*., 2004; Adey, 2006). This analysis indicates that, after teaching the CASE lessons for a period of one year, only eight of the participating teachers refer to metacognition as bringing one's thinking into consciousness, despite metacognition being one of the most prominent features of the methodology. Furthermore, only three teachers were able to distinguish between cognitive extension during the lesson (CE) and metacognitive thinking (MT). The analysis of the teachers' responses to the lesson reflections, researcher observations and responses to Q3 highlights that only one teacher (T17) was consistent in her ability to engage her students in metacognitive thinking. According to Adey (Adey *et al.,* 2004), it is generally not until the second year of the professional development programme that teachers are able to engage their students in metacognitive thinking. He proposes that this is due to the teachers' lack of metacognitive skills and understanding of the concept. The analysis described above supports this proposal, as the teachers who appear to have an understanding of the concept of metacognition were more successful in engaging their students in metacognitive discussions.

Furthermore, the teachers' ability to bring their students thinking into consciousness appears to have been a factor in their ability to bridge the schema from a CASE lesson to other areas of student learning. T17 is the only teacher who displays that she fully understands the concept of metacognition and is also the only teacher who consistently encourages her students to apply the thinking they engaged in to other contexts, as discussed in Chapter 6. This suggests that, in order to facilitate the transfer of students' thinking to other areas of learning, the teacher must first be aware of the thinking the students engaged in, and that this requires a sound understanding of metacognition. This analysis indicates that the teachers need further support in developing their understanding of metacognition and their ability to engage their students in metacognitive discussions. This is discussed in the next section.

7.5 Developing teachers' knowledge of metacognition in relation to CASE

It is widely believed that successful instruction requires teachers to have a combination of specific subject matter knowledge, general pedagogical knowledge and pedagogical content knowledge (Shulman, 1986). According to Zohar (2006) these requirements also apply to the teaching of metacognition. In order to engage their students in metacognitive discussions, teachers must first develop their own metacognitive knowledge and their pedagogical knowledge in the context of metacognition (Zohar, 2006). In order to have a comprehensive knowledge of metacognition, teachers need to:

- *have general theoretical knowledge about metacognition, especially to be familiar with, and to understand, definitions of the concept 'metacognition'; and,*
- *have the personal ability to practice metacognitive thinking with respect to classroom activities.*

*(*Zohar and Barzilai, 2013 p.128*)*

Pedagogies in the context of metacognition involve teaching strategies that can be employed in order to foster metacognition thinking in students. These include:

- informing learners about the usefulness and benefits of metacognition (Veenman *et al.*, 2006);
- introducing the 'language of thinking' into the classroom;
- modelling the use of a thinking strategy in a variety of specific contexts;
- encouraging students to reflect upon, talk about, evaluate and explain their thinking (Thomas, 2004).

The results of this study indicate that the teachers lacked sufficient knowledge of metacognition in order to engage their students in metacognitive discussions. At the end of the programme, the majority of participating teachers could not distinguish between cognitive extension and metacognitive thinking, despite its prominence within the CASE methodology. Recent literature has highlighted that there is a lack of research into teachers' metacognitive knowledge and it's effect on their metacognitive pedagogies (Zohar & Barzilai, 2013). However, two studies, Zohar (2006) and Ben-David and Orion (2012), showed that, prior to engaging in professional development aimed as improving teachers' understanding of metacognition, participating teachers did not possess sufficient knowledge in order to foster metacognitive thinking from their students. The results of this research study support these findings and suggest that the teacher's knowledge of metacognition was a factor in their ability to engage their students in metacognitive discussions. Teachers with a better understanding of metacognition were more successful in eliciting metacognitive thinking from their students. Therefore, one possible approach to improve teachers' pedagogies in the context of metacognition is to improve their knowledge of the concept.

One approach, which has shown to have positive effects in increasing teachers' knowledge of metacognition, is to develop the teachers' metacognitive skills (Ben-David & Orion, 2012). This involved the teachers developing their own metacognitive skills by engaging in, and reflecting on metacognitive activities as learners, and then as teachers. The teachers then implemented metacognitive activities in a classroom setting, and reflected on their metacognitive teaching experiences. In this study, the teachers were introduced to the concept of metacognition in relation to the CASE methodology, and strategies to elicit metacognitive thinking from their students. However, no explicit attempt was made to improve the teachers' own metacognitive thinking skills. Additionally, while the teachers in this study were encouraged to reflect on their teaching experiences, this was at a low level and the teachers generally reflected on the strategies they employed, rather than on their thinking processes. The approach used by Ben-David and Orion (2012) can be applied to developing teachers' knowledge of metacognition in relation to the implementation of the CASE methodology. In this approach, teachers:

- experience CASE first as learners to become familiar the lessons but to also develop their own metacognitive thinking.
- reflect on their metacognitive experiences as learners and as teachers. In doing so, the teachers' knowledge of metacognition should be made explicit, so that they can foster metacognitive thinking in their students (Zohar, 2006).

- are given sufficient time to implement the CASE lessons in a classroom setting and reflect on their teaching concentrating on their ability to elicit metacognitive thinking from their students. These reflections should be at a higher level, focusing on the teacher's thinking processes and evaluating their implementation, rather than discussing what was done.

Due to time constraints, the teachers in this study were not provided with the opportunity to engage with the lessons as learners. The teachers discussed the lessons and strategies to implement them in their classrooms. While this was sufficient to assist the teachers in their implementation of the concrete preparation, cognitive conflict and social construction aspects of the lessons, the teachers require further support to develop their pedagogies in the context of metacognition. Experiencing the lessons first as learners has the potential to:

Develop the teachers' metacognitive thinking skills

Increase the teachers' metacognitive knowledge

Improve the teachers' pedagogies in the context of metacognition

T17 echoes this sentiment:

> *Some teachers need to experience this approach to enable them to facilitate it in their own classrooms, so maybe a workshop where they work through a task in a similar manner, with discussion etc. might be a useful experience.*
>
> *(T17.Q3)*

Additional supports highlighted by the teachers in this study include; sample videos of teachers engaging their students in metacognitive discussions and observing/team-teaching with a more expert teacher.

Future implementation of the CASE methodology in Irish primary schools should focus on developing teachers' metacognitive knowledge and skills. Teachers require a sound understanding of metacognition so that they can foster metacognitive thinking in their students and relate this thinking to other areas of student learning. Teachers should be afforded the time to apply their metacognitive pedagogies in a classroom setting and reflect on their implementation. This reflection should concentrate not only what was done, but on the thinking processes that the teachers themselves engaged in.

Chapter 8

Conclusions and Implications

This chapter summarises the key findings from the study. The first section addresses the aims of the research outlined in Chapter 1. The second section makes recommendations for any future implementation of the CASE methodology in Irish schools.

The aim of this study was to evaluate whether the CASE methodology could be integrated into the teaching of science at all levels in the Irish primary school. CASE has previously been implemented at primary level in Ireland and had positive effects on students' thinking skills (Gallagher, 2007; McCormack, 2009). Therefore, in this study, it was decided that it would not be beneficial to assess the effects of the implementation on students' thinking skills, but to evaluate the teachers' implementation of the lessons. It was hoped that this would encourage the teachers to evaluate the methodology, and its effects on their classroom practices and students' thinking, beyond statistical testing. Areas of difficulty for the teachers, particularly relating to each 'pillar' of the lesson could be identified and used to inform any future implementation of the CASE methodology in Irish primary schools. The key findings are discussed with regard to the aims of the study.

1. Integrating the CASE methodology into the teaching of primary science in Ireland

The analysis described in Chapter 3 highlighted that there is a large degree of overlap between the objectives of the CASE activities and those of the primary science curriculum in relation to scientific content and skills. The CASE methodology also fits with the aims of the primary curriculum in that students should:

- be active in the construction of their own understanding,
- develop their HOTS,
- be able to transfer and apply their thinking to other areas and,
- learn how to learn.

(DES, 1999a)

Some adaptions were made to the existing CASE activities to make them appropriate for use in Irish primary schools. These adaptions are listed below:

- A number of lessons at the 5th and 6th class level were split in two and the language simplified to make them suitable for use with primary school students.
- The teacher guidelines were extended at the 5th and 6th class levels to include additional science content and suggested dialogue between teacher and students.
- A practical element was introduced to a number of lessons at the 3rd and 4th class level as they were considered too "paper-based"
- Lessons at the Junior Infants to 1st class levels were implemented as whole-class activities rather than with small groups of students.

Adapting the existing CASE activities and mapping them onto the curriculum, created a continuous programme of thinking through science for the Irish primary school. Overall, the CASE methodology integrates well with the objectives of the primary curriculum and the positive effects of CASE, discussed in Chapter 2, indicate it is a suitable approach to address the concerns regarding the development of Irish students' HOTS. As previously mentioned, the aim of this research was not to measure the effects of the CASE methodology on the students' cognitive development; however, future long-term research could involve analysing the effects of experiencing the CASE methodology from Junior Infants to 6th class on students cognitive development and academic achievement.

2. Identifying areas of difficulty for teachers

The analysis described in Chapter 6 highlighted that the teachers' implementation of the lessons generally improved as the programme progressed. The teachers' focus shifted from the science content in the lessons to concentrating on the students thinking. The teachers prompted their students to revisit any previous thinking that had engaged in that would help to solve the task, and encouraged their students to question, reason, provide valid explanations for their answers and to think independently. The teachers felt that a sound knowledge of the underlying theory was a key factor in implementing the lessons successfully and that, as they became more familiar with the methodology, they were better able to guide their students through the cognitive conflict and manage class discussions. Team teaching proved beneficial for the teachers, as they were able to observe alternate strategies to guide the students through the pillars of the lesson and assimilate these into their teaching. The teachers also cited the suggested dialogue in the lesson plans, focus group discussions and the information in the folders provided as supports, which assisted them in their implementation of the lessons. The teachers' knowledge of the scientific content covered in the lessons does not appear to have been a factor in their implementation; however the 3rd and 4th class teachers would benefit from additional content knowledge on the topics of 'Heat', 'Forces' and 'Electricity'. The analysis described in Chapter 6 also highlighted that the teachers' implementation, and confidence in their implementation, was specific to the individual. The teachers' implementation of the lessons varied at all class levels, and there does not appear to be one lesson, or group of lessons that all of the teachers found difficult. The teachers' confidence also varied, and while some teachers were successful in their implementation, they were not very confident and vice versa.

However, engaging students in metacognitive discussions proved to be an area of difficulty for teachers at all class levels. Metacognition has previously been highlighted as one of the more difficult tasks for cognitive acceleration teachers (Adey *et al*., 2004; Adey, 2006). The analysis of the teachers' implementation of the CASE lessons supports this, and indicates that this is due to a lack of understanding of the concept. The majority of teachers were unable to distinguish between cognitive extension during the lesson (CE) and metacognitive reflection (MT), and only three teachers referred to metacognition as 'consciousness of thinking'. While provoking the students to extend their cognitive capabilities is an essential aspect of the CASE methodology, it does not encourage the students to become conscious of their thinking in any way, making it more difficult for the students to apply their new reasoning to an unrelated context. The teachers' knowledge of metacognition appears to have been a factor in their implementation of this pillar, as teachers with better understanding of metacognition were generally more successful in engaging their students in metacognitive discussions. Furthermore, as the teachers often failed to bring the students' thinking into consciousness, they were unable to facilitate the transfer this thinking to other learning areas. Generalising the students' thinking is essential so that it can be applied outside the context of CASE.

In addition to being a central aspect of the CASE methodology, consciousness of thinking is a valuable skill that can be applied not only in school, but in everyday life. Through planning, regulating and evaluating, students are more in control of their thinking and can solve problems more efficiently. The Special Education Support Services (SESS) highlights that the ability to think metacognitively is a valuable skill that enables students to 'learn how to learn'.

> *Factual information fades fairly quickly. However, throughout any further education or working career, an individual will constantly be faced with new problems to solve, new information to make sense of and new tasks to complete. In equipping pupils with the knowledge of how to learn we can set them up for these future challenges. (SESS, 2009)*

The SESS highlight that metacognitive thinking skills are beneficial to students of all abilities and encourages the student to take responsibility for their learning. Strategies suggested by the SESS to develop students' metacognitive skills include:

- Making students aware of the importance of metacognition,
- Developing students' metacognitive knowledge and skills and,
- Fostering a learning environment that values and promotes metacognitive awareness.

The SESS acknowledge that the teachers' understanding of metacognition is key in promoting students' metacognitive awareness. The findings of this study indicate that the teachers did not have sufficient knowledge of metacognition to encourage metacognitive thinking in their students. As discussed in Chapter 7, one possible approach to increase teachers' knowledge of metacognition involves teachers developing their own metacognitive skills by engaging in, and reflecting on CASE activities as learners, and then as teachers. This approach has the potential to improve teachers' pedagogies in the context of metacognition.

Future Implementation

The outcomes of this study indicate that the CASE methodology can be integrated into the teaching of science in Irish primary schools. Future implementation should be on a whole-school basis to ensure that students are continuously cognitively stimulated and to allow the teachers to collaborate and share ideas. Teachers that participated in the pilot study stated that the lessons were easier to implement when they could discuss any issues that they were having, and possible strategies to overcome them with their colleagues. It is therefore essential to have the support of the school principal involved. The management of the school involved with this project was very supportive of the study. The principal was enthusiastic about creating a coherent programme of thinking science throughout the school and encouraged all the teachers to participate. The principal allocated sufficient time so that the teachers could participate in focus group discussions and designated a 'science room' where the CASE lessons could be held.

Due to time and cost restrictions it is not feasible to have a full-time researcher working in schools, as was the case in this study. Implementation of the CASE methodology on a larger scale could involve numerous schools participating in professional development simultaneously. Teachers from different schools can collaborate, share ideas and develop a sense that change is possible. The professional development model employed could follow the model used by the team at King's College as discussed in Section 2.9 and involve a number of INSET days and in-class coaching. As with the original professional development, the PD should reflect the pedagogy of CASE itself. Teachers should be provided with some challenge, encouraged to talk and listen to each other, and reflect on how their perspectives have changed. The INSET days and school-visits should be spread out over the course of the PD to allow the teachers multiple opportunities to engage with the CASE methodology and obtain feedback on their implementation. Particular emphasis should be placed in developing teachers' understanding of metacognition and their ability to elicit metacognitive thinking from their students.

Future implementation of the CASE methodology in Irish primary schools should provide the teachers with the opportunity to engage with the lessons as learners. In this way, the teachers can develop, and make explicit, their own metacognitive knowledge and develop their pedagogies in metacognition.

Conclusions

Overall, this study advocates the integration of the CASE methodology into the teaching of primary science in Ireland. Previous studies have shown CASE to be effective at increasing Irish students' thinking skills (Gallagher, 2008; McCormack, 2009), while the findings from this study demonstrate that the CASE methodology overlaps with the objectives of the primary science curriculum in relation to scientific content and skills. Therefore, the CASE methodology appears to offer a suitable approach to develop Irish primary students' thinking skills within the context of science, and in general. Eliciting metacognitive thinking from students proved to be an area of difficulty for teachers at all class levels due to a lack of understanding of the concept. Recommendations for future implementation of the CASE methodology in Irish schools include expanding the professional development to involve numerous schools simultaneously and focus on developing teachers' knowledge of, and pedagogies in metacognition.

References

Adey, P. (1999). The Science of Thinking, and Science for Thinking: A Description of Cognitive Acceleration through Science Education (CASE) *Innodata Monographs 2. International Bureau of Education.*

Adey, P. (2004). *Accelerating the development of general cognitive processing In:* Demetriou, A. and Raftopoulos, A. (Eds.) *Cognitive Developmental Change. Theories, Models and Measurements.* Cambridge University Press, pp.296-317.

Adey, P. (2006). Thinking in science - thinking in general? *Asia-Pacific Forum on Science Learning and Teaching,* 7(2)

Adey, P. (2008). *Let's Think! Handbook.* London: GLAssessment Limited.

Adey, P., Csapó, B., Demetriou, A., Hautamäki, J. & Shayer, M. (2007). Can we be intelligent about intelligence? Why education needs the concept of plastic generalbility. *Educational Research Review,* 2(2), pp.75-97.

Adey, P., Hewitt, G., Hewitt, J. & Landau, N. (2004). *The professional development of teachers: Practice and theory.* Netherlands: Kluwer Academic Publishers.

Adey, P., Nagy, F., Robertson, A., Serret, S. & Wadsworth, P (2003). *Let's Think through Science! Seven and Eight Years.* London: nferNelson.

Adey, P., Robertson, A. & Venville, G. (2001). *Let's Think! Five and Six Year Old.* London: nferNelson.

Adey, P., Robertson, A. & Venville, G. (2002). Effects of a cognitive acceleration programme on year 1 pupils. *British Journal of Educational Psychology,* 72 pp.1-25.

Adey, P. & Shayer, M. (1994). *Really Raising Standards.* London: Routledge.

Adey, P. & Shayer, M. (2011). The effects of cognitive acceleration – and speculation about causes of these effects. *Modeling Instruction, Arizona State University.*

Adey, P., Shayer, M. & Yates, C. (1989). *Thinking Science: The curriculum materials of the CASE project.* London: Thomas Nelson and Sons.

Adey, P., Shayer, M. & Yates, C. (2003). *Thinking Science!.* Third Edition, Professional Edition ed. Cheltenham: Nelson Thornes.

Adhami, M., Johnson, D. & Shayer, M. (1998). *Thinking Maths: The Cognitive Acceleration in Maths Education Project. .* London: NFER-Nelson.

Anderson, M. (1992). *Intelligence and development: A cognitive theory.* Oxford: England: Blackwell.

Anderson, M. (2001). Annotation: Conceptions of intelligence. *Journal of Child Psychology & Psychiatry & Allied Disciplines,* 42(3), pp.287.

Arce, C. & Garling, T. (1989). Multidimensional scaling. *Anuario De Psicologia,* 43pp.63-80.

Armstrong, P.I., Day, S.X., McVay, J.P. & Rounds, J. (2008). Holland's RIASEC model as an integrative framework for individual differences. *Journal of Counseling Psychology,* 55(1), pp.1-18.

Ball, D.L. & Cohen, D.K. (1996). Reform by the book: What is - or might be - the rold of curriculum materials in teacher learning and intructional reform. *Educational Researcher,* 25(9), pp.6.

Ben-David, A. & Orion, N. (2012). Teachers' voices on integrating metacognition into science education. *International Journal of Science Education,* 35(18), pp.3161-3193.

Blagg, N., Ballinger, M. & Gardner, R. (1988). *Somerset Thinking Skills Course.* Oxford: Basil Blackwell.

Blumenfeld, P.C., Soloway, E., Marx, R.W., Krajcik, J.S., Guzdial, M. & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist,* 26(3), pp.369.

Bond, T. (1976). *BLOT: Bond's Logical Operations Test* Townsville: Townsville College of Advanced Education.

Borg, W.R. & Gall, M.D. (1983). *Educational research: an introduction.* 4th Ed. New York: Longman.

Brainerd, C. (1978a). *Piaget's theory of intelligence.* Englewood Cliffs, N.J: Prentice-Hall.

Carroll, J.B. (1992). Cognitive Abilities: The state of the art. *Psychological Science (Wiley-Blackwell),* 3(5), pp.266-270.

Case, R. (1985). *Intellectual development: A systematic reinterpretation.* New York: Academic Press.

Cattle, J. & Howie, D. (2008). An evaluation of a school programme for the development of thinking skills through the CASE@KS1 approach. *International Journal of Science Education,* 30(2), pp.185-202.

Cha, J., Kim, S. & Lee, Y. (2009). Application of multidimensional scaling for marketing-mix modification: A case study on mobile phone category. *Expert Systems with Applications,* 36(3), pp.4884-4890.

Clerkin, A. (2013). PIRLS and TIMSS 2011: Teachers and teaching practice *IN:* Anonymous *In E. Eivers & A. Clerkin (Eds.). (2013). National Schools, international contexts: Beyond the PIRLS and TIMSS test results. Dublin: Educational Research Centre. .* Dublin: Educational Research Centre, pp.77-104.

Cohen, D. (1983). *Piaget, critique and reassessment.* London: Croom Helm.

Cooper, C. & Boyd, J. (1999). Creating sustained professional growth through collaborative reflection. *IN:* Brody, C.M. and Davidson, N. (Eds.) *Professional Development for Cooperative Learning.* Albany: State University of New York Press, pp.49-62.

Coulter, M. (2012). *Teaching outdoor and adventure activities: Describing, analysing and understanding a primary school physical education professional development.* PhD Thesis. Dublin City University.

Creswell, J.W. (2003). *Research design: qualitative, quantitative, and mixed methods approaches.* 2nd Ed. Thousand Oaks, Calif: Sage Publications.

De Bono, E. (1976). *Teaching Thinking.* London: Temple Smith.

Demetriou, A., Efklides, A. & Platsidou, M. (1993). The architecture and dynamics of developing mind: Experimental structuralism as a frame for unifying cognitive development theories. *Monographs of the Society for Research in Child Development,* 58

Demetriou, A. & Raftopoulos, A. (1999). Modeling the developing mind: From structure to change. *Developmental Review,* 19(3), pp.319-368.

Denscombe, M. (2003). *The good research guide for small-scale social research projects.* Second Ed. Maiden head, Philadelphia: Open University Press.

Department of Education and Skills (2012). *Science in the primary school 2008: Inspectorate evaluation studies.* Dublin: Stationery Office.

Department of Education and Science (1999a). *Department of Education and Science Primary School Curriculum.* Dublin: Stationery Office.

Department of Education and Science (1999b). *Primary School Curriculum: Science.* Dublin: Department of Education and Science. The Stationery Office.

Department of Education and Science (1999c). *Primary School Curriculum: Science: Teacher Guidelines.* Dublin: The Stationery Office.

Department of Education (1971). *Curaclam na Bunscoile: Lámhleabhar an oide (Primary School Curriculum: Teacher's handbook) (Vols. 1-2). Dublin: Stationery Office. .* Dublin: Stationery Office.

Donaldson, M. (1978). *Children's minds.* London: Fontana Press.

Dotson, M.J. & Clark, J.D. (2004). The impact of promotions on hotel decision choice: A demographic study. *Journal of Hospitality and Leisure Marketing,* 11(2), pp.81-95.

Endler, L. & Bond, T. (2001). Cognitive development in a secondary science setting. research in science education, 30(4):403–416, 2001.

Endler, L. & Bond, T. (2008). Changing science outcomes: Cognitive acceleration in a US setting. *Research in Science Education,* 38(2), pp.149-166.

Everson, H.T. & Tobias, S. (1998). The ability to estimate knowledge and performance in college: A metacognitive analysis *Instructional Science,* 26(1), pp.65-79.

Feuerstein, R., Rand, Y., Huffman, M.B. & Miller, R. (1980). *Instrumental Enrichment.* Baltimore: University Park Press.

Fisher, R. (1998). Thinking about thinking: Developing metacogntion in children. *Early Child Development & Care,* 141pp.1.

Flavell, J.H. (1963). *The developmental psychology of Jean Piaget.* New York: Van Nostrand.

Flavell, J.H. (1977). *Cognitive development.* Englewood Cliffs, N.J: Prentice-Hall.

Flavell, J.H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist,* 34(10), pp.906-911.

Forgas, J.P. (1979). Multidimensional scaling: a discovery method in social psychology. *IN:* Ginsburg, G.P. (Ed.) *Emerging strategies in social psychology.* London: Wiley,

Fullan, M. (1993). *Change forces: probing the depth of educational reform.* London; New York: Falmer Press.

Gallagher, A. (2008). *Developing thinking with four and five year old pupils: The impact of a cognitive acceleration programme through early science skill development.* Masters Thesis. Dublin City University.

Garet, M., Porter, A.C., Desimone, L., Birman, B. & Yoon, K.W. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal,* 38(4), pp.915-945.

Gash, H.; McCloughlin, T.; Bajd, B.; Chocholousková, Z.; Krnel, D.; Prknová, P.; & Robert, S. (2007) Teachers' views of the learning environments in their classrooms In: McCloughlin, T.J.J.; Finlayson, O. & Mulhall, C. (Eds.) Proceedings of the primary science symposium: science live for teachers. RDS / CASTeL, Dublin pp. 21 – 24.

Gelman, R. (1978). Cognitive development. *Annual Review of Psychology,* 29(1), pp.297.

Georghiades, P. (2004). From the general to the situated: Three decades of metacognition. *International Journal of Science Education,* 26(3), pp.365.

Ghaye, A. & Ghaye, K. (1998). *Teaching and learning through critical reflective practice.* London: David Fulton.

Gillham, B. (2000). *Case study research methods.* London: Continuum.

Gillham, B. (2005). *Research interviewing: the range of techniques.* Maidenhead, Berkshire, England; New York: Open University Press.

Ginsburg, H.P. & Opper, S. (1987). *Piaget's Theory of Intellectual Development.* Third ed. Pearson College Div.

Glesne, C. & Peshkin, A. (1992). *Becoming qualitative researchers: An introduction.* New York: Longman.

Goswami, U.C. (2008). *Cognitive development: the learning brain.* Hove, East Sussex; New York: Psychology Press.

Gouge, K. & Yates, C. (2006). *Think Ahead! Drama.* London: nferNelson.

Gouge, K. & Yates, C. (2008). *Let's Think through Literacy!* London: nferNelson.

Guskey, T.R. (2003). What makes professional development effective? *Phi Delta Kappan,* 84(10), pp.748.

Haller, E.P., Child, D.A. & Walberg, H.J. (1988). Can comprehension be taught? A quantitative synthesis of "metacognitive" studies. *Educational Researcher,* 17(9), pp.5-8.

Hamaker, A.K. & Backwell, J. (2003). *Cognitive Acceleration through Technology Education: Teacher Guidelines and Pupil Task Pages.* Taunton: Nigel Blagg Associates.

Hautamäki, J., Kuusela, J. & Wikström, J. (2002). CASE and CAME in Finland: "The second wave". *Harrogate: 10th International Conference on Thinking. .*

International Assessment of Educational Progress (IAEP) (1989). *International assessment of educational progress (IAEP). A world of difference: Summary report of an international assessment of mathematics and science, report no. 22-CAEP-02.* New Jersey: Educational Testing Service.

Inhelder, B. & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence; an essay on the construction of formal operational structures; Translated by Anne Parsons and Stanley Milgram.* [New York]: Basic Books.

Irish National Teachers Organisation (1992). *Irish national teachers organisation primary science education in Ireland: Issues and research (no 16/92).* Dublin: INTO.

Irish National Teachers Organisation (1996). *Primary science curriculum - an evalutionary process.* Dublin: INTO.

Irish National Teachers Organisation (2005). *The primary school curriculum. INTO survey,* Dublin: INTO.

Iqbal, H.M. & Shayer, M. (2000). Accelerating the development of formal thinking in Pakistan secondary school students: Achievement effects and professional development issues. *Journal of Research in Science Teaching,* 37pp.259-274.

Izmailov, C.A. & Sokolov, E.N. (1991). Spherical model of colour and brightness discrimination. *Psychological Science,* 2(249), pp.259.

Jaworska, N. & Chupetlovska-Anastasova. (2009). A review of multidimensional scaling (MDS) and its utility in various psychological domains. *Tutorials in Quantitative Methods for Psychology,* 5(1), pp.1-10.

Jones, M. & Gott, R. (1998). Cognitive acceleration through science education alternative perspectives. *International Journal of Science Education,* 20(7), pp.755-768.

Joyce, B. & Showers, B. (1980). Improving in-service training: The messages of research. *Educational Leadership,* 37(5), pp.379-385.

Joyce, B. & Weil, M. (1986). *Models of teaching .* 3rd ed. Englewood Cliffs NJ: Prentice Hall.

Kruskal, J.B. (1964). Multidimentional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychrometrika,* 29(1),

Lai, E.R. (2011). *Metacognition: A literature review. Pearson Research Report.* Retrieved from: www.pearsonassessments.com/research May 2013: Research Report.

Larkin, S. (2006). Collaborative group work and individual development of metacognition in the early years. *Research in Science Education,* 36(1), pp.7-27.

Larkin, S. (2008). Metacogntion: Becoming concious of thinking *IN:* Adey, P. (ed.) *Let's Think! Handbook. A guide to cogntive acceleration in the prmary school.* London: GL Assessment, pp.33-45.

Lipman, M. (1998). Teaching students to think reasonably: Some findings of the.. *Clearing House,* 71(5), pp.277.

Lipman, M., Sharp, M. & Oscanyan, F. (1980). *Philosophy in the Classroom* 2nd Edition ed. Philadelphia: Temple University Press.

Little, J.W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis,* 15(2), pp.129-151.

Lourenço, O., & Machado, A. (1996). In defense of Piaget's theory: A reply to 10 common criticisms. *Psychological Review,* 103(1), pp.143-164.

Magno, C. (2010). The role of metacognitive skills in developing critical thinking. *Metacognition Learning,* 5pp.137-156.

Markman, E. (1973). The facilitation of part-whole comparisons by use of the collective noun "family". *Child Development,* 44(4), pp.837-840.

Martin, M., Mullis, I., Beaton, A., Gonzalez, E., Smith, T. & Kelly, D. (1997). *Science achievement in the primary school years: IEA's third international mathematics and science study (TIMSS).* MA: Boston Centre: Chestnut Hill.

Martin, M., Mullis, I.V.S., Foy, P. & Stanco, G.M. (2012). *TIMSS 2011 international results in science.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Martinez, M.E. (2006). *What is metacognition?* Phi Delta Kappan, 696-699.

Masnick, A.M., Valenti, S.S., Cox, B.D. & Osman, C.J. (2010). A multidimensional scaling analysis of students' attitudes about Science Careers. *International Journal of Science Education,* 32(5), pp.653-667.

Mbano, N. (2003). The effects of a cognitive acceleration intervention programme on the performance of secondary school pupils in malawi . *International Journal of Science Education,* 25pp.71-87.

McCormack, L. (2009). *Cognitive acceleration across the primary-second level transition .* PhD Thesis. Dublin City University.

McGarrigle, J., & Donaldson, M. (1974). Conservation accidents. *Cognition, (*3) pp.341-350.

McGuinness, C. (2000). ACTS (activating children's thinking skills) - A methodology for enhancing thinking skills throughout the curriculum. *IN:* ACTS (activating children's thinking skills) - A methodology for enhancing thinking skills throughout the curriculum. *ESRC Teaching and Learning Programme.* University of Leicester

McGuinness, C. (2005). *Teaching thinking: Theory and practice* The British Psychological Society.

Morgan, D.L. & Krueger, R.A. (1998). *The Focus Group Kit. (vols. 1- 6).* London: Sage Publications.

Morse, J.M. & Niehaus, L. (2009). *Mixed method design: principles and procedures.* Walnut Creek, CA: Left Coast Press.

Murphy, C. (2013). PIRLS and TIMSS 2011: Science Items: Context and Curriculum. *IN:* Anonymous*In E. Eivers & A. Clerkin (Eds.). (2013). National Schools, international contexts: Beyond the PIRLS and TIMSS test results. Dublin: Educational Research Centre. .* Dublin: Educational Research Centre. pp.177-200.

Nagy, P., & Griffiths, K. (1982). Limitations of recent research relating Piaget's theory to adolescent thought. *Review of Educational Research,* 52(4), pp.513-556.

National Council Curriculum Assessment (2008). *Primary curriculum review, phase 2. Final report with recommendations.* Dublin: NCCA

National Foundation for Educational Research. (1979). *Science Reasoning Tasks.* 2 Oxford Road East, Windsor, Berks: NFER Publishing Co.

Nzelek, J.B., Austin-Lane, J. & Null, C.H. (2001). Multidimensional scaling analyses of the perceived social structure of informal groups. *Group Dynamics: Theory, Research and Practice,* 5(3), pp.200-207.

Organisation for Economic Co-operation Development. (2013). *Draft Science Framework - PISA 2015.* OECD.

Oliver, M., Venville, G. & Adey, P. (2012). Effects of a cognitive acceleration programme in a low socioeconomic high school in regional australia. *International Journal of Science Education,* 34(9), pp.1393-1410.

Pascual-Leone, J. (1976). Metasubjective problems of constructing cognition: Forms of knowing and their psychological mechanisms. *Canadian Psychological Reviews,* 17pp.110-125.

Penuel, P.W., Fishman, B.J., Yamaguchi, R. & Gallagher, L.P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal,* 44(4), pp.921-958.

Piaget, J. (1952). *The Origins of Intelligence in Children.* New York: International Universities Press.

Piaget, J. (1963). *The Psychology of Intelligence.* N.J. Littlefield: Paterson.

Piaget, J. (1976). *The grasp of consciousness: Action and concept in the young child.* Cambridge, MA: Harvard University Press.

Piaget, J. & Inhelder, B. (1969). *Psychology of the Child.* New York: Basic Books.

Piaget, J., Inhelder, B. & Pomerans, A.J. (1974). *The child's construction of quantities: conservation and atomism.* London: Routledge and Kegan paul.

Putnam, T. & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher,* 29(1), pp.4-15.

Robertson, A. (2006). *Let's Think! Early Years.* London: nferNelson.

Robertson, A. & Adey, P. (2004). *Let's Think through Science! Eight and Nine Years.* London: nferNelson.

Schiffman, S., Reynolds, L. & Young, F.W. (1981). *Introduction to Multidimensional Scaling: Theory, Methods and Applications.* New York: Academic Press.

Schrnelkin, L.P., Gilbert, K.A. & Silva, R. (2010). Multidimensional scaling of high school students' perceptions of academic dishonesty. *High School Journal,* 93(4), pp.156-165.

Shayer, M. (1997). *The long-term effects of cognitive acceleration on pupils' school achievement.*

Shayer, M. (1999a). *GCSE 1999: Added-value from schools adopting the CASE Intervention.* London: King's College Centre for the Advancement of Thinking.

Shayer, M. (1999b). Cognitive acceleration through science education II:Its effects and scope. *International Journal of Science Education,* 21(8), pp.883-902.

Shayer, M. (2003). Not just Piaget; not just Vygotsky, and certainly not Vygotsky as alternative to Piaget. *Learning and Instruction,* 13(5), pp.465-485.

Shayer, M., Adhami, M., Robertson, A. & Twiss, S. (2004). *Let's Think through Maths! Five and Six.* London: nferNelson.

Shayer, M. & Beasley, F. (1987). Does instrumental enrichment work? *British Educational Research Journal,* 13(2), pp.101-119.

Shayer, M., Johnson, D. & Adhami, M. 1999. Does 'CAME' work? (2) Report on Key Stage 3 results following the use of the Cognitive Acceleration in Mathematics Education, CAME, project in Year 7 and Year 8. *Proceedings of the British Society for Research into Learning Mathematics,* 19(2),

Shayer, M., Küchemann, D.E. & Wylam, H. (1976). The distribution of Piagetian stages of thinking in British middle and secondary school children. *British Journal of Educational Psychology,* 46(2), pp.164-173.

Shayer, M. & Wylam, H. (1978). The distribution of Piagetian stages of thinking in British middle and secondary school children II 14- to 16- year olds and sex differentials. *British Journal of Educational Psychology,* 48(1), pp.62-70.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher,* 15pp.4-14.

Siegler, R. (1998). *Children's thinking.* 3rd Ed. Upper Saddle River, N.J: Prentice Hall.

Smith, G. (2012) *The Western Seaboard Science Project: An innovative model of professional development to enhance teaching and learning of primary science.* PhD Thesis. National University of Ireland, Maynooth.

Smylie, M.A. (1996). From bureaucratic control to building human capital: The importance of teacher learning in education reform. *Educational Researcher,* 25(9), pp.9-11.

Spearman, C. (1923). *The Nature of Intelligence and Principle of Cognition.* London: Macmillan.

Special Education Support Services (2009). *Metacognition for the classroom and beyond: Differentiation and support for learners.* SESS. Retrieved from: www.sess.ie January 2014.

Stake, R.E. (1995). *The art of case study research/Robert E. Stake.* Thousand Oaks, Calif: Sage.

Swartz, R. & Parks, S. (1994). *Infusing the teaching of critical and creative thinking into content instruction: A lesson design handbook for the elementary grades.* California: Critical Thinking Press & Software.

Tashakkori, A. & Teddlie, C. (1998). *Mixed Methodology: Combining qualitative and quantitative approaches.* Thousand Oaks, CA: Sage.

Teaching Council. (2012). *Code of Professional Conduct for Teachers.* Second Ed. Teaching Council.

Tellis, W. (1997). Introduction to case study. *The Qualitative Report,* 3(2).

Thomas, G.P. (2003). Conceptualisation, development and validation of an instrument for investigating the metacognitive orientation of science classroom learning environments: The metacognitive orientation learning environment scale – science (MOLES-S). *Learning Environments Research,* 6(2), pp.175-197.

Trickey, S. & Topping, K.J. (2004). Philosophy for children: A systematic review. *Research Papers in Education,* 19(3), pp.365-380.

Varley, J., Murphy, C. & Veale, Ó (2008). *Science in primary schools: Phase 1.research commissioned by NCCA, final report.* Dublin: NCCA.

Veenman, M.V.J., Van Hout-Wolters, B.H.A.M. and Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning,* (1), pp.3-14.

Venville, G., Adey, P., Larkin, S. & Robertson, A. (2003). Fostering thinking through science in the early years of schooling. *International Journal of Science Education,* 25(11), pp.1313-1331.

Von Wright, J. (1992). Reflections on reflections. *Learning and Instruction,* 2(1), pp.59-68.

Vygotsky, L.S. (1978). *Mind in society: the development of higher psychological processes.* Cambridge: Harvard University Press.

Vygotsky, L.S. (1986). *Thought and language.* Cambridge, MA: MIT.

Wadsworth, B.J. (1987). *Piaget's Theory of Cognitive Development.* Second Ed. New York: Longman Inc.

Woolfolk, A. (1987). *Educational Psychology.* 3rd Ed. Englewood Cliffs, N.J.: Prentice-Hall.

Woolfolk, A., Hughes, M. & Walkup, V. (2008). *Psychology in Education.* Harlow. Pearson Education.

Young, F.W. & Hamer, R.M. (1987). *Multidimensional scaling--History, Theory, and Applications.* Hillsdale, N.J: L. Erlbaum Associates.

Zohar, A. (2006). The nature and development of teachers' meta-strategic knowledge in the context of teaching higher order thinking. *The Journal of Learning Sciences,* 15(3), pp.331-377.

Zohar, A. (1999). Teachers' metacognitive knowledge and instruction of higher order thinking. *Teaching and Teachers' Education,* 15pp.413-429.

Zohar, A. & Barzilai, S. (2013). A review of research in science education: Current and future directions. *Studies in Science Education,* 49(2), pp.121-169.

Zohar, A. & Ben-David, A. (2008). Explicit teaching of meta-strategic knowledge in authentic classroom situations. *Metacognition and Learning,* 3pp.59-82.

Zohar, A. & Peled, B. (2008). The effects of explicit teaching of meta-strategic knowledge on low- and high-achieving students. *Learning and Instruction,* 18pp.337-353.

Zohar, A. (2013a). Scaling up higher order thinking in science classrooms: The challenge of bridging the gap between theory, policy and practice. *Thinking Skills and Creativity,* 10(0), pp.168-172.

Zohar, A. (2013b). Challenges in wide scale implementation efforts to foster higher order thinking (HOT) in science education across a whole school system. *Thinking Skills and Creativity,* 10(0), pp.233-249.

Appendix A

Interview 1

Teacher Interview- January 2011

When working through the CASE lessons, do you think the students are doing anything differently than in the ordinary science lessons?

When working through the CASE lessons, do you think the students are thinking differently than in the ordinary science lessons?

Can you see a difference in the students' ability to work in groups/listen to each other/ give their opinion?

How well do you think the CASE lessons integrate with the primary science curriculum?

In the lessons completed so far, can you see how the students are guided through the 5 pillars of CASE?

Are you able to identify the area of cognitive conflict in the lessons?

How confident are you in your ability to guide your students through the cognitive conflict/social construction?

Do you think you will be able to take 15 minutes every day to complete a CASE lesson with a small group? (Junior)

Have you being doing science lessons as well as the case lessons since the beginning of the year. If so, what topics have you covered?

Are there any additional supports that you think you need to help you with your implementation of the lessons

Appendix B

Interview 2

Teacher Interview Rubric

CASE Methodology

- ➢ Overall, what's your opinion on the CASE methodology?
- ➢ On a scale of 1-5, how do you rate the CASE methodology?
- ➢ Do you think the CASE lessons differ from other science lessons?
    - How so?
- ➢ How confident do you feel in your knowledge of the theory behind the CASE lessons? (the pillars and how to manage them)
- ➢ Is there one pillar you think is more important than another?
    - Which one(s)?
    - Why?
- ➢ Is there pillar that you feel is <u>not</u> as important as the others?
    - Which one?
    - Why?
- ➢ Do you think it is important to be familiar with the background theory in order to teach the lessons?
    - Why (not)?
- ➢ Do you think you need to learn more of the background theory?
    - What?
    - Do you think it would have an effect on how you teach the lessons?
    - How?
- ➢ On a scale of 1-5, how confident do you feel in your ability to guide your students through the pillars of a CASE lesson?
    - Did this confidence increase as the programme progressed?
    - Why?
- ➢ Have you had any change in opinion of the CASE methodology from the beginning to now?
    - What?

Their Teaching

- ➢ Do you think your approach to teaching CASE lessons is the same as your other lessons?
    - How?
- ➢ Overall, how confident are you in your science content knowledge dealt with in the CASE lessons?

- Do you think that you need to know more of the science content?

➢ Do you think that it will be easier to teach the CASE lessons next year having already taught them?
    - Why/Why not?
➢ Is there any particular aspect of the lessons that you find difficult /don't like?
    - What?
    - Do you think you have improved at this as the programme progressed?
    - Why?
➢ How did you find not telling the students the answer and allowing them to figure it out for themselves?
    - Do you think you improved at this as the programme progressed?
➢ Do you think you have gained anything (skills wise) from teaching CASE lessons?
    - Do you think you can use this when teaching your other lessons?
➢ Have you used any aspect of the CASE methodology in your other lessons?(E.g. incorporating the schema (reasoning patterns)/trying not to focus on the one right answer/questioning /focusing on the students more/ introducing a cc)
    - What?
➢ Did you discuss the CASE lessons with your colleagues?
    - What did you discuss?
    - Did this help?
    - Why?

<u>Their Students</u>

➢ How did your students react to the lessons?
➢ On a scale of 1-5 how much did your students enjoy the lesons?
    - Which parts of the lessons do you think they enjoy?
➢ Is there any aspect to the CASE lessons that you think your students find difficult?
    - What?
    - Did this improve as the programme progressed?
    - Why?
➢ How did your students react to the cognitive challenge aspect to the lessons?
➢ How did your students find the metacogntion aspect of the lesson?
    - Do you think they improved at 'thinking about their thinking' as the programme progressed?
    - Why?
➢ Do you think the lessons have had any effect on the students?

- What?

- Can you see any improvement in their ability to:
  - work in pairs
  - listen to each other
  - not focus on the right answer
  - verbailse their thought process
- Are the any differences between the <u>thinking process</u> the students undergo in a "normal" lesson and a CASE lesson?
  - What?

Appendix C

Questionnaire 1

Section 1: Biographical Information

Q1. Name:

Q2. Years of Teaching Experience:

Q3. a) What class did you teach last year?

b) What class are you teaching this year?

Q4. How many children are in the class?

Q5. Teaching Qualification:

Section 2: Your Background in Science Education

Q1a. While at college did you take any science education modules? **Y / N**

Q1b. Do you feel that the science modules you took at college sufficiently prepared you to teach science at primary level? **Y / N**

If no, please indicate why not

____
____
____
____

Q2a. Did you study science while at secondary school? **Y / N**

Q2b. If yes, please specify which level and subject.

Level (e.g. Leaving Certificate)	**Subject** (e.g. Chemistry)

Q3. Do you know what is taught at second level with regards to science? **Y / N**

Q4 a. Have you completed a course in Science Education since the completion of your teaching qualification?
(include summer/evening/weekend course, certificate, diploma, degree) **Y / N**

Q4 b. If yes, specify course/s and date/s

Course	**Venue**	**Year**

Section 3: You and Science

Q.1. How important do you consider the following in the development of a school plan for science

	Very important	Important	Fairly important	Not important
Providing a broad and balanced programme				
Maximum participation by children				
Providing opportunities for individual achievement				
Working scientifically				
Designing and making				

Q2. The Science curriculum is divided into 4 Strands – Living Things, Energy and forces, Materials, Environmental awareness and care.
Please answer the following questions based on each strand

(a) Last year I taught this strand to my class

Strand	Yes	No
Living things		
Energy and forces		
Materials		
Environmental awareness and care		

(b) If yes, indicate how frequently you taught this strand

Strand	1-2 lessons	3-4 lessons	5-6 lessons	More than 6 lessons
Living things				
Energy and forces				
Materials				
Environmental awareness and care				

(c) Indicate how important you think this strand is at primary level

Strand	Very Important	Important	Fairly Important	Not Important
Living things				
Energy and forces				
Materials				
Environmental awareness and care				

(d) Indicate how important you think each skill is at primary level

Skill	Very Important	Important	Fairly Important	Not Important
Questioning				
Observing				
Predicting				
Investigating and experimenting				
Estimating and measuring				
Analysing				
Recording and communicating				
Designing and making				

(e) Indicate how comfortable you are teaching the *content* of the strands to your class.

Strand	**Very comfortable**	**Comfortable**	**Fairly comfortable**	**Uncomfortable**
Living things				
Energy and forces				
Materials				
Environmental awareness and care				

(f) In your own situation what constraints inhibit the implementation of the Science strands. Tick as many as apply.

	Living Things	**Energy and Forces**	**Materials**	**Environmental Awareness**
Lack of equipment				
Unsuitability teaching area				
Safety				
Lack of confidence				
Size of class				
No clear defined programme				
Lack of adequate training				
Low status of strand				
Maintaining class discipline				
Too much class organisation				
Too much planning				
Fear of failure				

Section 4: Your experience of teaching Science

Q1. Identify the factors that have informed your planning for teaching science **this year***(tick as many as are appropriate)*

The Science Curriculum	
Books on Science Education	
Science Education Journals	
Other notes (college, science courses attended, those of other colleagues)	
Videos/DVD's	
Your own experience of teaching science	

Other (please explain)

____

____

____

Q2. Which of the following areas do you place emphasis on in your teaching of science?

	A Lot	**Some**	**Little**
Scientific skills development			
Social development			
Development of knowledge and understanding of science			
Develop an interest in science and the world			

Q3. Which of the following skills do you place emphasis on in your teaching of science this?

	A Lot	**Some**	**Little**
Questioning			
Observing			
Predicting			
Investigating and experimenting			
Estimating and measuring			
Analysing			
Recording and communicating			
Designing and making			

Q4. On average how many times per week, did you teach science last year?

Less than once	
Once	
Twice	
Three times	

Q5. On average how much time per lesson, do you devote to the teaching of science?

No Time	
Less than 30 minutes	
31-45 minutes	
46-60 minutes	
More than 60 minutes	

Q6. Indicate which teaching methods you incorporate into your Science Education lessons

	Very Frequently	**Frequently**	**Rarely**	**Never**
Guided discovery				
Group teaching				
Integration with other subjects				
Direct teaching				

Q7. Identify your strengths as a teacher of Science

____
____
____
____
____

Q8. Identify your weaknesses (if any) as a teacher of Science

____
____
____
____
____

Q9. Indicate your own confidence levels with regard to the following aspects of a Science lesson

	Very Confident	**Confident**	**Not Very Confident**	**Not confident**
Lesson planning				
Use of equipment				
Skill development				
Pair/group activities				
Whole class activities				
Class management				
Safety				

Q10. Indicate what you believe are the most important factors in implementing a quality science programme

	Very Important	**Important**	**Not Very Important**	**Not Important**
Regular in service training				
Small class sizes				
Adequate science equipment				
Adequate advice and support within the school				

Q11. Any further comment you wish to make with regard to your teaching of science

____
____
____
____
____

Section 5. Curriculum planning and resourcing

Q1. Do you keep records of children's attainment in Science? **Y / N**

Q2. Do you keep a record of the content covered in Science by your class? **Y / N**

Q3. If yes, is this record made available to the next class teacher at the beginning of the school year? **Y/N**

Q4. Have you supported your colleagues in your school in teaching science? **Y / N**

If yes, indicate how

____
____
____
____

Q5. Do you and any other teachers in your school work together to plan for/teach Science? **Y / N**

If yes, please indicate how. If no, please indicate why not

____
____
____
____

Can you describe a science lesson you taught last year that you think was successful?
Topic?
What did you do? /What did your students do?
What do you think made this lesson particularly successful?

Thank you for your time and honesty in answering this questionnaire.

Appendix D

Questionnaire 2

<u>Teacher Questionnaire – June 2013</u>

Teacher Name:

<u>Section 1: The Cognitive Acceleration through Science Education (CASE) Methodology</u>

Q.1 Overall, what's your opinion on the CASE methodology?

Q.2 Have you had any change in opinion of the CASE methodology from the beginning of the year to now? Please explain.

Q.3 On a scale of 1-5, how do you rate the CASE methodology for teaching science in your classroom? (1 = low; 5 = high) **1 2 3 4 5**

Q.4 How do you think the CASE lessons differ from other science lessons that you have taught?

Q.5 How confident do you feel in your knowledge of the pillars of the CASE methodology? (1 = low, 5= high)

1 2 3 4 5

Q6a. How confident do you feel now in your ability to guide your students through the pillars of a CASE lesson? (1 = low, 5= high) **1 2 3 4 5**

Q6b. Did your confidence in this increase over the last year? Why do you think this happened?

Q7a. Within a CASE lesson, is there one pillar that you think is more important than the others? If so, which pillar and why?

Q7b. Is there a pillar that you feel is **not** as important as the others? If so, which pillar and why?

Section 2: Your Students

Q.8 On a scale of 1-5, how much do you think your students enjoyed the CASE lesons overall?

1 2 3 4 5

Q.9 Which parts of the lessons do you think they enjoy?

Q.10 Is there any aspect to the CASE lessons that you think your students find difficult? If so, what?

Q.11 Did this improve as the programme progressed? Please explain.

Q.12 Do you think that there are any differences between the thinking processes the students undergo in CASE lesson and other science lessons? If yes, how?

Q.13 Overall, how do you feel your students reacted to the cognitive challenge aspect to the lessons?

Challenged ☐ Overwhelmed ☐ Antagonistic ☐ Anxious ☐ Oblivious ☐

Q.14 Do you think the lessons have had any effect on your students? If yes, how?

Q.15 On a scale of 1 – 5, how would you rate your students improvements in their ability to: (please tick):

(1 = no improvement, 5 = significant improvement)

Work in pairs	**1**	**2**	**3**	**4**	**5**
Listen to each other	**1**	**2**	**3**	**4**	**5**
Not focus on the right answer	**1**	**2**	**3**	**4**	**5**
Verbalise their thought process	**1**	**2**	**3**	**4**	**5**
Think for themselves	**1**	**2**	**3**	**4**	**5**

Q.16 Overall, on a scale of 1 – 5, how successful do you think your students were at 'thinking about their own thinking' (1 = not very successful, 5 = very sucessful)

1 2 3 4 5

Q.17 Do you think they improved at this as the programme progressed? **Y / N**

Section 3: Your Teaching

Q.18 Overall, how confident are you in your knowledge of the science content dealt with in the CASE lessons? (1= not confident, 5 = very confident) **1 2 3 4 5**

Q.19 Do you think that you need additional science knowledge to deliver the CASE lessons? **Y / N**

Q.20 Do you think that your own science content knowledge has improved from the beginning of the year to now? **Y / N**

Q.21 Do you think that it will be easier to teach the CASE lessons next yearafter this years programme? **Y / N**

Q.22 Is there any particular aspect of the lessons that **you** find difficult/don't like? Why?

Q.23 Do you think you have improved at this as the programme progressed? **Y / N**

Q.24 Do you think you have gained anything (skills wise) from teaching CASE lessons? If so, what?

Q.25 Has this programme influenced how you are teaching science. If yes, please explain.

Q.26 On a scale of 1 -5, please inndicate how important you think each skill is for primary level science
(1 = not very important, 5 = very important)

Skill	**Very Important**	**Important**	**Fairly Important**	**Not Important**
Questioning				
Observing				
Predicting				
Investigating and experimenting				
Estimating and measuring				
Analysing				
Recording and communicating				
Designing and making				

Q.27 Please indicate how comfortable you are teaching the *content* of the strands to your class.

Strand	**Very Comfortable**	**Comfortable**	**Fairly Comfortable**	**Not Comfortable**
Living things				
Energy and forces				
Materials				
Environmental awareness and care				

<u>**Section 4**: **Next phase**</u>

Q.28 What supports provided (if any) do you feel helped you in implementing the CASE lessons?

Q.29 Do you intend to teach science through the CASE methodology next year? **Y / N**

Q.30 Are there any additional supports that you feel may help you in implementing the CASE lessons next year? If yes, what?

Q.31 Did you discuss the CASE lessons with the other teachers in your year group? If yes, what sorts of things did you discuss?

Q.32 Did these discussions help with the implementation of the CASE lessons? **Y / N**

Q.33 On a scale of 1-5 how well do you think you and the other teachers in your year group collaborated? (1= not confident, 5 = very confident) **1 2 3 4 5**

Q.34 On a scale of 1 – 5, how well do you agree with the following statements: (1 = strongly disagree, 5 = strongly agree)

I feel that I had enough resources	**1**	**2**	**3**	**4**	**5**
I felt supported by the researcher	**1**	**2**	**3**	**4**	**5**
I feel my confidence in teaching science has improved over the course of the year	**1**	**2**	**3**	**4**	**5**
I feel that I need longer/more time teaching the CASE lessons	**1**	**2**	**3**	**4**	**5**
I feel I need more support to implement the CASE lessons	**1**	**2**	**3**	**4**	**5**
I will be more confident teaching the lessons next year	**1**	**2**	**3**	**4**	**5**
There are aspects of the CASE methodology that I will use in my other teaching	**1**	**2**	**3**	**4**	**5**

Thank you for taking the time to fill this out.

Appendix E

Questionnaire 3

Metacognition in the Classroom

Name:

Class Level that you are teaching this year:

1. Please place a tick next to the situation(s) that you think encourage metacognitive thought. (You may tick more than one).

a.	Teacher asking questions during the lesson to challenge the students thinking	
b.	Teacher encouraging students to explain their answers	
c.	Teacher encouraging their students to reflect on what they have learned during the lesson	
d.	Teacher encouraging their students to reflect on the thinking they engaged in during the lesson	
e.	Teacher allowing their students to discuss their ideas with each other	

2. Do you currently use metacognition in your classroom? Yes/No

3. Please rate how well you agree with the following statements:
(Please circle one. 1= do not agree, 5= fully agree)

a.	I fully understand the concept of metacognition	**1**	**2**	**3**	**4**	**5**
b.	I am confident in my ability to generate metacognitive thinking in my students	**1**	**2**	**3**	**4**	**5**
c.	I think that metacognition is an important aspect of student learning	**1**	**2**	**3**	**4**	**5**

4. Can you please explain you answer to question 3c? Why do you think metacognition is/is not important?

5. If you do not feel confident in your ability to generate metacognitive thought in your students, are there any additional supports that you feel may help develop your ability?

Thank you for taking the time to fill out this survey

Appendix F

Lesson Reflection

Lesson Reflection

Teacher: Lesson Title:

Date:

Before the lesson: (1 = not at all; 5 = a lot)

1. How confident were you in your scientific content knowledge on this topic?

1 2 3 4 5

2. How confident were you in your ability to manage the cognitive conflict and the class discussion well?

1 2 3 4 5

The lesson:

3. Overall, how successful do you think the lesson was?

1 2 3 4 5

4. To what extent were the students engaged throughout the lesson?

1 2 3 4 5

5. How successful was your introduction to the lesson?

1 2 3 4 5

6. How did you set up the concrete preparation at the beginning of the lesson? What questions did you ask?

7. What incident/discussion arose in the lesson that caused the '**Surprising Event'**(*cognitive conflict*) for the students? Was this brought about by you or by the students?

8. How did the students react when faced with the cognitive conflict situation?

Challenged ☐ Overwhelmed ☐ Antagonistic ☐ Anxious ☐

Oblivious ☐

9. How successful were you at guiding the students through the 'Surprising event'/class discussion stage?

1 2 3 4 5

10. What questions did you ask to guide the students through the 'Surprising event'?

11. Did the students resolve the cognitive conflict? **YES/NO**

12. How successful were you at not telling the students the answer?

1 2 3 4 5

13. What discussions evolved during the part of the lesson? Were there any differences in the discussions in each group?

Thinking about thinking (*Metacognition*)

14. How successful were you at getting the students to think about their thinking after the lesson?

1 2 3 4 5

15. What strategies did you use to get the students to think about their thinking during the Metacognition part of the lesson?

Bridging

16. In what way ere you able to bridge the CASE lesson to any other topic they have covered/will cover?

17. Is there any aspect of your teaching that you think you did well in this lesson? (Questioning etc)

18. Is there any area that you think you can improve on in the next lesson?

Appendix G

Observation Rubric

Teacher:

Lesson: **Date:**

1	Overall, success of lesson	1	2	3	4	5
3	Implementation of concrete preparation	1	2	3	4	5
4	Guiding students through cognitive conflict/managing social construction	1	2	3	4	5
5	How successful was the teacher at not telling the students the answer	1	2	3	4	5
6	How successful was the teacher at eliciting metacognitive thinking in their students	1	2	3	4	5

Notes:

Lesson: **Date:**

1	Overall, success of lesson	1	2	3	4	5
3	Implementation of concrete preparation	1	2	3	4	5
4	Guiding students through cognitive conflict/managing social construction	1	2	3	4	5
5	How successful was the teacher at not telling the students the answer	1	2	3	4	5
6	How successful was the teacher at eliciting metacognitive thinking in their students	1	2	3	4	5

Notes: