The Western Seaboard Science Project: An Innovative Model of Professional Development to Enhance the Teaching and Learning of Primary Science

By

Gregory Smith

A thesis submitted in fulfilment of the requirements for

the degree of Doctor of Philosophy

Education Department, National University of Ireland Maynooth

Supervisor: Dr. Pádraig Hogan

2012

CONTENTS

List of Tables

List of Figures

Audio Recordings

Nine audio recordings were completed during the research. All the recordings are accessible using Real Player. All nine are contained on one disc. For example Audio 2, 3:43 – 4:04 means the second audio clip beginning at minute 3:43 and ending at minute 4:04.

Audio 1: Teacher interview (Cluster 1)

Audio 2: Teacher interview (Cluster 2)

Audio 3: Teacher interview (Cluster 3)

Audio 4: Walton school pupils (pre)

Audio 5: Thomson school pupils (pre)

Audio 6: Boyle school pupils (pre)

Audio 7: Walton school pupils (post)

Audio 8: Thomson school pupils (post)

Audio 9: Boyle school pupils (post)

Glossary of Terms and Abbreviations

CPD – Continuing Professional Development

DES – Department of Education and Skills

IAP – Irish American Partnership

ICDU – In-Career Development Unit

INTO – Irish National Teachers' Organisation

NCCA – National Council for Curriculum and Assessment

PCK – Pedagogical Content Knowledge

PCSP – Primary Curriculum Support Programme

PDST – Professional Development Service for Teachers

PPDS – Primary Professional Development Service

PSC – Primary School Curriculum

PD – Professional Development

OECD – Organization for Economic Co-operation and Development

SDPI – School Development Planning Initiative

SLSS – Second Level Support Service

TES – Teacher Education Service

TL21 – Teaching and Learning for the 21st Century (Ireland)

WSSP – Western Seaboard Science Project

Acknowledgments

I am indebted to my supervisor, Dr. Pádraig Hogan, for his painstaking guidance, motivation, advice and patience during this study. Pádraig was a friend and mentor of mine before I began this study and I am more than happy to say that our friendship and my admiration for him have survived this test.

My sincere thanks goes to Dr. Paula Kilfeather, Head of Biology, St. Patrick's College, for all her support and belief in my work. I would also like to thank the Irish American Partnership (especially Joe Leary and Mary Sugrue McAleer) and the Department of Education and Skills who gave me the opportunity to pursue this doctoral thesis. Without them and their support this thesis would not have been possible.

A special thanks goes to the teacher participants and their pupils for their willingness to participate in my study. I thank you for generously giving of your time.

On a personal note I would like to thank my wonderful children, Pádraic, Niall and Niamh for their understanding and support throughout this study. Finally, to my wife Mary, I could not have done this research without you. You consistently gave me emotional support, encouragement and understanding to complete this thesis.

Declaration

I hereby certify that this thesis, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy, is my own work and all sources of information used have been acknowledged within the text of my work. I also certify that the work is original and has not been previously submitted for any other award.

Abstract

The quality of teaching is a very significant factor in influencing pupils' attitudes and interest to learn primary science. However, a large body of research literature shows that many primary teachers' background knowledge of science is inadequate, resulting in many of them lacking the confidence and competence to teach science effectively. In many countries professional development of teachers has been seen as a key strategy to improving teacher quality. Addressing the issue of teacher quality with the traditional "one off" or short modular model of professional development has been shown to have little effect on teaching or learning back in the classroom. In response to this, a model of professional development was developed for this study based on the characteristics of effective professional development from a wide body of contemporary literature. Key features of the model included: active participation, meaningful collaboration, continuity, and feedback.

This study was concerned with investigating the influence of a two year long professional development programme on primary teachers' attitudes towards primary science, their confidence and competence in teaching science, and pupils' attitudes towards school science. The specific aims of the study were to:

- investigate the extent to which a professional development programme designed in the light of recent research findings can bring about improvements in confidence, competence and attitudes among primary teachers where the teaching of science is concerned;
- investigate the extent to which pupils' attitudes towards school science are improved;
- break down the insulation and isolation teachers experience in their day-to-day professional lives;
- develop sustainable "learning communities" between participating teachers.

The research involved 24 teachers and 281 pupils from fifteen small rural primary schools. The study was undertaken using a mixed methods approach. The methods of data collection were pre-and post-intervention questionnaires, semi-structured interviews, and cognitive tests.

Findings from this study showed that the participants became substantially more confident and competent in teaching primary science. Most significantly, teachers made dramatic changes in the way they taught science, resulting in their pupils becoming more

positive and motivated to learn science. Evidence from the study also showed that the programme made significant inroads into (1) breaking down the traditional culture of teacher isolation and (2) building up a professional learning community. These are important findings that should influence planners of future professional development programmes, especially those programmes being designed for teachers in small rural primary schools. By the end of Year One of the programme, teachers were actively exchanging resources, sharing ideas, engaging in innovative methodologies and pedagogical discussions with their colleagues.

The experience from this study suggests that if professional development for teachers in primary science is to be really fruitful it should include the following key features: (1) on-going and long-term support for teachers; (2) emphasis on content and pedagogy; (3) actively engage participants; (4) collaborative in nature; (5) provide feedback and reflection; and (6) have appropriate and systematic procedures for evaluation.

Chapter 1
Introduction to Study

Introduction

This study is an exploration and critical review of an experimental professional development project for teachers of primary science in 15 rural schools in the West and North-West of Ireland. It seeks to find a successful and sustainable way of remedying a shortfall in capacity in science teaching on the part of teachers in rural and smaller primary schools. In this Introduction the background to the study is presented in order to set the context in relation to professional development for teachers in Irish primary schools (section 1.1). Section 1.2 examines the rationale for the study. This section is divided into two subsections: the first subsection (1.2.1) provides a brief review of the supports needed by primary teachers to teach science. The second (1.2.2) identifies in a preliminary way some key issues relating to primary teachers' knowledge of science and attitude to teaching science. The specific purposes of the study, together with the research questions, and their significance are then presented successively (section 1.3 and section 1.4). The Introduction concludes with an overview of the study as a whole (section 1.5).

1.1 Background to the study

From the early 1990s to the middle of the first decade of this century, the Irish economy surpassed that of most other countries, particularly in science and technology related industries. Ireland was at this time, one of the most globally integrated countries in the world. It was also been a time of unparalleled change, development and reform in Irish education. This was influenced by organisations such as the Organisation for Economic Co-operation and Development (OECD) and the publication of various White Papers in Education by governments. Examples include: *Charting Our Education Future* (1995, White Paper), *Ready to Learn* (1999, White Paper on Early Education), *Learning For Life* (2000, White Paper on Adult Education). Legislative reform has also influenced education change, such as: the *Education Act,* (1998), the *Education and Welfare Act,* (2000); the *Teaching Council Act,* (2001); and, the *Education for Persons with Special Educational Needs Act*, (2004).

Our society is now defined as a "knowledge-based society". Education is at the centre of the knowledge-based society. As Dr. Don Thornhill Chairman, National Competitiveness Council Ireland (NCC, 2009) stated:

> The quality of our education system has been a critical foundation for our economic and social progress...it is essential that our policy makers and educators are ambitious about the potential of our pupils and educators to build on current strengths and to ensure that a highly-skilled population is able to thrive in an increasingly competitive global environment. It is imperative that our education system continues to improve its performance.
>
> (NCC, 2009, p. 5)

It is clear that education for the 21^{st} century will no longer prepare people for secure, lifelong employment. From a socio-economic perspective a main concern for educational provision will be to furnish pupils with a broad variety of skills needed for the new knowledge-based economy. Professor John Coolahan, one of Ireland's leading educational policy researchers, has emphasised that "the knowledge/learning society, which is emerging requires very different characteristics from the traditional inherited model of schooling shaped by industrial society" (Coolahan in Hogan et al., 2005, p. i). The "knowledge-based society" requires different and broadening roles for teachers, including: adapting to new technologies, use of a broad range of teaching approaches, collaboration with fellow professionals, and not least, more systematic reflection on their classroom practice. Furthermore, Coolahan stresses that to meet the developing requirements of such a knowledge/learning society, schools and teachers are being challenged to turn schools into "active learning communities", enabling teachers and pupils to develop the skills, knowledge and attitudes essential to become lifelong learners in such a society. It is apparent that teachers will need renewed support if they are to cultivate the skills necessary for their new role. Creating opportunities for on-going professional development is crucial in this regard.

Traditionally, professional development in Irish schools has focused primarily on supplementing curriculum change with in-service, usually when a new curriculum is being introduced. This "in-service" has tended to be in the form of "one-off" and "one-size-fits all" gatherings where experts from outside schools transmit knowledge to teachers. The deficiencies of this traditional in-service training are clearly recognized (Little, 1993; Hawley & Valli 1999; Wilson & Berne 1999). Examples of deficiencies as cited by Riding (2001), include the statement: “it is too fragmented, unproductive, inefficient, unrelated to practice, and lacking in intensity and follow up” (p. 283). Furthermore, Riding maintains “traditional in-service sessions generally prove to be ineffective in changing teachers’ practice and have little, if any, effect back in the classroom” (p. 283).

Current literature on professional development recommends a move away from the isolated lecture-style in-service workshop, towards professional development that is on-going and gives teachers opportunities to: collaborate with their colleagues sharing practices and knowledge, reflect on their pedagogic practice, focus on pupil learning, and be involved in decision making (Kennedy 1998; Supovitz & Turner 2000; Hogan et al., 2007). The work of the present study will build upon current international thinking on professional development. Steered by the findings of the international research literature, the study will explore new possibilities for teachers’ professional development. Through promoting and monitoring an active developmental project for teachers, it will focus on the enhancement of the teaching and learning of science in fifteen small rural primary schools (two/three teacher schools). It will provide opportunities for the participating primary teachers to develop:

- a collaborative professional culture, in contrast to more traditional cultures of professional isolation and insulation;
- regular links with teaching colleagues in other schools;
- greater pedagogical expertise and deeper subject knowledge;
- the skill of reflective practice in a supportive and safe environment.

Historically, small rural schools are underserved on account of their isolation from other teachers - the size of the school may mean that there are only one or two colleagues with whom to exchange ideas and advice, unlike the situation in a large school. Such schools are also isolated from research and development institutions, such as third-level colleges and the regional Education Centres. This can result in them being out of touch with optimal teaching strategies. The present study hopes to make encouraging inroads into breaking down this professional isolation.

1.2 Rationale for the study

The past decade has seen much reform in science education in Ireland, especially in curricula review and development at primary and secondary level. A major reform has taken place in the provision of science at primary level with the introduction of the revised Primary School Curriculum (PSC) in 1999 (Department of Education and Science, 1999) and implementation in 2003.

The new science curriculum seeks to "promote curiosity and enjoyment, so that the pupils develop a lasting interest in science [and to] promote its relevance and help children to develop informed attitudes towards scientific and environmental issues" (DES, 1999a, p. 12), in other words *placing* science in context of everyday life for the children. Prior to the PSC, science in the 1971 curriculum was taught under the umbrella of Social and Environmental Studies and elementary science was only included as a subject for fifth and sixth classes (Department of Education, 1971). However, a lack of in-service support, class size, insufficient resources and a lack of alignment between the primary and post-primary curricula resulted in a degree of dissatisfaction among teachers and serious under-implementation of the curriculum (Irish National Teachers' Organisation, 1976). Teaching science was not a priority for teachers as its status as a subject was low on a teacher's tight time schedule (Department of Education, 1983).

The revised science curriculum (DES, 1999a) is child-centred in its approach. It embraces the development of concepts, skills and attitudes, which are to be promoted simultaneously. The curriculum promotes the use of various teaching approaches in order to encourage positive attitudes towards science. There is a strong emphasis on "hands-on" classroom science, with increased pupil based practical work and a more exploratory approach to teaching and learning. However, concerns quickly emerged in a number of areas, namely: teacher confidence and competence in teaching science, teachers' attitudes to teaching science and the level of support available for science teaching. Palmer (2001) stresses many Irish primary teachers have limited or no knowledge of science or teaching practices in science. The government has tried to address these concerns through the provision of in-service training "curriculum days" (2 days) for teachers and on-going support through the Primary Curriculum Support Project (PSCP).

In 2008, the National Council for Curriculum and Assessment (NCCA) carried out a review of the primary science curriculum (Varley et al., 2008). This review drew attention to a number of concerns regarding the teaching of science, including poor teacher confidence when teaching certain concepts and skills in science. One of the main recommendations put forward in the review was the provision of on-going comprehensive in-service support for teachers. It can be seen from the international research literature (e.g., Summers & Kruger, 1992; Harlen & Holroyd, 1997; Goodrum et al., 200; Appleton, 2003) that primary teachers' confidence, competence and attitudes towards teaching science is a world-wide concern. The literature on how to improve the teaching of science focuses in particular on two areas: (a) support, in the form of professional development and (b) improving teacher confidence and competence (improving teachers' knowledge of science), including developing positive attitudes towards teaching science. Salient issues in both areas are identified below, with references in each case to the relevant research literature.

1.2.1 Support for primary teachers

Professional development for teachers has been defined as a systematic attempt to bring about transformation in their classroom practices (Guskey, 2002) and contribute to higher learning outcomes for pupils. Hughes (1991, p. 58) argues that the main goal of professional development is primarily to bring about progressive change in a number of dimensions of teachers' work. This attempted change pursues three general outcomes for an individual teacher:

- Change in the teacher's beliefs and attitudes;
- Change in the teacher's content knowledge;
- Change in the teacher's instructional practices.

Hughes also argues that professional development which is focused on aspects like these, will lead to a higher quality of teaching and consequently, to sustained improvements in learning for the pupils being taught. Furthermore, he argues that a well-planned and implemented professional development programme is central in the effort to bring about productive change in the school and classrooms, and to achieve more effective pupil learning and quality teaching.

Recent research has shown that particular supports are critical for teachers in times of new curriculum implementation. Peers et al. (2003) identified professional development as an important factor to support teacher growth during the implementation of a new primary science curriculum (2003, p. 89). Studies carried out by Bennett et al. (1992), cited by Holroyd and Harlen (1996, p. 323) attribute the increase in confidence by primary science teachers in England and Wales between 1989 and 1991 to the investment of resources, both human and material, in supporting these teachers. Murphy and Beggs (2005) carried out a major study to establish a synopsis of the present status of primary science in the UK. They reported that effective continuing professional development provision in science for primary teachers is probably the most important factor in bringing about improvements in primary science learning and teaching. In a major study carried out with Australian primary teachers, Goodrum et al. (2001) revealed concerns regarding teachers' limited knowledge of science and low teacher confidence. They recommended the provision of on-going professional development to address these concerns. It seems logical therefore, to suggest that similar supports for Irish primary teachers would have a beneficial effect on their teaching of science. This present study will be arguing that, to enhance science learning in primary schools across Ireland, teachers need extensive, on-going and well-focused opportunities in effective professional development settings. Such efforts need to develop both subject content knowledge and pedagogical practices in science teaching.

1.2.2 Teachers' knowledge of science and attitude to teaching science

It is very common for primary teachers in Ireland and many western countries to teach several subjects to their pupils. Primary teachers frequently have to teach subjects that did not feature greatly in their own second level education and/or pre-service teacher training. Science can be one such subject and many who teach it can have a very limited knowledge of it. Goodrum et al. (2001) stress primary teachers' knowledge in science is very uneven and this can result in many lacking confidence and competence in teaching science. Research by Harlen and Holroyd (1997) in the UK showed that inadequate science knowledge was an important feature that influenced primary teachers' confidence in teaching science.

Educational research has recently focused attention on affective outcomes of learning – particularly pupils' attitudes to the subjects they study. This attention has arisen because affective variables are seen to be just as essential as cognitive variables in affecting the quality of learning and in predicting learning and other outcomes (Kobella, 1988). Haladyna et al. (1982) identified three key features impacting on pupils' attitudes to science: the pupil, the teacher and the learning environment. Research by Haladayana et al. (1982), Simpson and Oliver (1990) and Woolnough (1994), indicates three areas of a teacher's behaviour that are significant: (a) the teachers' attitude towards science and science teaching; (b) teachers' mode of communication to their pupils; and (c) their pedagogical approach. They found that teacher quality was especially significant in enhancing pupils' attitudes to science. Simon and Oliver (1990) have argued that, if primary teachers are not as motivated to teach science as much as they are other subjects, then their pupils will not be given appropriate experience in science during vital phases of their learning. Rennie et al. (1985) found teachers' attitudes and behaviours regarding science and technology affect their classroom practice and have a significant influence on the attitudes of their pupils.

It is important to explore in an Irish context (1) how primary teachers' confidence and competence in teaching science affects their pupils' attitudes towards school science and (2) whether a different model of professional development can enhance teaching and learning of science in primary schools. The present study will investigate the impact of an innovative participatory model of professional development on: primary teachers' attitudes towards science and science teaching and explore how they impact on their pupils' attitudes towards school science.

1.3 Purpose of the study and research questions

The main purpose of this study is to develop a model of professional development in science education with primary teachers in 15 small rural schools, in order to enhance the teaching and learning of primary science. Specifically the study has four main aims:

1. Investigate the extent to which this model can help bring about improvements in confidence, competence, attitudes and levels of knowledge among primary teachers where the teaching of science is concerned;
2. Investigate the extent to which pupils' attitudes towards school science are influenced by developmental changes in their teachers;
3. Break down the insulation and isolation that teachers experience in their day-to-day professional lives – developing *meaningful* collaboration using a workshop model and a Virtual Learning Environment;

4. Develop sustainable “learning communities” between the participating teachers and investigate what features of this model could be incorporated into continuing professional development for primary teachers more widely.

The following research questions, each in relation to beneficial developments in science teaching, are addressed in this study:

- What changes in teachers’ confidence in teaching science and competence in relation to knowledge of the science curriculum occurred during the study?
- What changes in teachers’ attitudes to teaching science occurred during the study?
- What changes in teachers’ classroom practice occurred during the study?
- What changes in pupils’ attitudes occurred during the study?
- What changes in pupils’ engagement and collaboration in hands-on science activities occurred during this study?
- What aspects of the intervention programme promoted or inhibited teachers’ subject confidence, competence and attitudes?
- What, aspects if any of the model, influenced the development of “learning communities”?

1.4 Significance of the study

This study hopes to contribute to the field of professional development of primary teachers in primary science. It seeks to investigate the professional practices, principles and approaches which are most suitable and effective for the professional growth of primary teachers. Its educational significance lies in its potential to enlighten teachers about their own practices and ways of examining what is occurring in their classrooms. This study provided the researcher with an opportunity to enhance primary science teaching and learning in small rural schools through an innovative model of professional development. It also provided the participants with an opportunity to reflect on, and enhance the teaching and learning of science in their classroom, and to voice their own thoughts and ideas about what are effective ways for them to teach science and for their pupils to learn science. Its main significance lies in its efforts to establish an informed and promising research base for primary science teaching in an Irish context. It can contribute to deepening the understanding of a professional development support model that is needed to produce learning opportunities for teachers. The findings and recommendations of this research will seek to add to existing knowledge on professional development, and contribute to national policy on professional development for teachers of primary science.

1.5 Overview of study

This section identifies in outline, an advanced conceptual map of the thesis and the concerns of each chapter. Each chapter begins with an introduction to inform the reader about what will be explored in each chapter. The thesis is divided into two parts. Part I consists of Chapters, Two, Three, Four, and Five. The purpose of these chapters is to establish a richly informed context to ensure that as many areas of investigation are "tapped into" to illuminate the position of primary science in Ireland, carry out the research and appraise the significance of its findings and practical advances. The first two chapters deal with developments in policy and practice in primary science education, internationally and in Ireland. The remaining two chapters review the research literature on science teaching and on professional development for teachers.

Chapter Two provides the reader with a brief overview of recent developments and reforms in science education internationally. It also investigates their influence on the teaching and learning of science in school, especially at primary level. The third chapter provides a chronological account of changes and developments in primary science in Irish schools since the 1800s. It also examines key aspects the present primary science curriculum – aims, content, process and implementation. The final part of the chapter identifies a number of concerns for primary science in Irish schools and explores some of the relevant international research pertaining to the implementation of the primary science curriculum.

Chapters Four and Five investigate and analyse the literature that forms the background and rationale for addressing the research questions in this study. A literature review of research findings on attitudes to science is undertaken in Chapter Four. It considers the significance of attitudes when teaching science, especially teachers' and pupils' attitudes to science education. Research into the different methods of measuring attitudes is also investigated. The final part probes two key factors affecting teachers' confidence in teaching science: teacher proficiency in science and teacher pedagogical content knowledge. The literature review in Chapter Five examines: the types of professional development that are available to teachers, the factors that make continuing professional development (CPD) effective, the various models of professional development that could be appropriate to this study, and the importance of evaluating professional development programmes.

Part II of the thesis consists of five chapters and carries out a type of research that is designed to promote change. The central theme of this research – investigating the impact of professional development on teachers' attitudes and confidence in teaching science – is a complex social activity. To address the challenges of such complex issues a number of research strategies have emerged, such as: case studies, ethnography, phenomenology, grounded theory, and action research. The research design used in the present study is influenced by: the type and amount of data being sought, the type of intervention being made to promote productive change, and the relationship of the researcher to the programme (see Chapter Six section 6.3). With these factors in mind, the study uses a combination of research approaches including questionnaires, interviews, monitoring, and a strong element of action research. The action research is carried out by the participants themselves at the level of classroom practice, and by the researcher at the level of continuing professional development.

Chapter Six establishes a rationale for employing an action research approach. It describes the methodological approaches that have been used in the study, as well as the data collection procedures. The chapter also analyses the key features of the intervention model used in this study. It concludes with a discussion on quality assurance of data collected and ethical considerations. Chapters Seven and Eight are concerned with the analyses and explanation of the quantitative and qualitative data. A statistical analysis of data collected from the teachers' questionnaires and examination of data obtained from interviews and monitoring templates is offered in Chapter Seven. Chapter Eight is concerned with analysing data collected from pupil questionnaires and interviews. Chapter Nine is an in-depth study of pupils and teachers in three participating schools. Detailed information about pupils' and teachers' attitudes to science in their classrooms are compared and contrasted.

Chapter Ten reviews some key developments and benefits that resulted for the participants and their schools during the lifetime of the project. These include the breaking down of the professional insulation and isolation that teachers experience and the promotion of a professional learning community. The final part of the chapter is concerned with a commentary on some of the challenges that the study faced. Finally, Chapter Eleven reviews the major findings of the study with reference to the research questions. This is followed by consideration of the implications of this study for the professional development of primary science in Irish schools. The limitations of the study, recommendations for future professional development, and avenues for further research are also reviewed.

Chapter 2

Science Education for the 21st Century

Introduction

This chapter provides an investigation into the influences of recent research-informed developments in science education on practices of science teaching in schools. It also investigates the various roles of science education and the importance of science in primary school. The chapter is divided into two parts.

The first part (section 2.1) gives a brief historical account of recent developments and reforms in science education. It critically investigates the tenor of the current international reform agenda exemplified by the United States and the United Kingdom. These countries were chosen because of their influence in science education reform at an international level. This section is divided into three subsections, the first (2.1.1) explores the post Sputnik reforms in science education. The second (2.1.2) addresses the science literacy crisis of the 1980s. The final subsection (2.1.3) examines the influence of developments in educational psychology on science education.

The second part of the chapter (section 2.2) focuses on the goals of science education and interrogates the grounds offered for promoting the place of science education in the primary curriculum. It is divided into three subsections: scientific literacy (2.2.1), economic and social wellbeing (2.2.2), and educational benefits to studying science (2.2.3). The chapter concludes with a summary of key issues (section 2.3).

2.1 Developments and reforms in science education in the last half century

The last century has seen the role of science education change back and forth between investigation, finding facts, elucidation and verification and arriving at principles. Prior to the mid-1950s, science curricula were centred on text books that portrayed science as a body of information, a body of separated facts and generalisations that called for rote memorisation.

The past 50 years, have seen several waves of reform in science education in many Western countries. In this section the researcher aims to review some prominent trends in science education over the last five decades. This is by no means a complete review, rather a survey of the main highlights. The researcher addresses two major reforms in science education: (a) Post Sputnik science education reform, and (b) The science literacy crisis. Their influence and impact on curriculum development in school science is then discussed.

2.1.1 Post sputnik science education reform

The launch of *Sputnik* in 1957, (which saw the USA fall behind the USSR in the space race) evoked a shock around the Western world. Science education, especially in the United States and the UK, became a major focus of attention. Scientists, science educators and the public in general agreed that science education was in a state of "crisis". Educational experts argued that one of the key reasons for this "crisis" was the relatively low quality of the existing science curricula (De Jong, 2007, p. 15). In the two decades that followed, new science curricula were developed by scientists and educators for use by classroom teachers. The main objective of these curricula was to increase the number of pupils pursuing careers in science (symbolised by the Sputnik space race). The National Science Foundation (NSF) and the Nuffield courses, respectively, dominated US and British science education during the 1960s, and 1970s. The main aims of these courses included: (1) focusing on understanding basic concepts and processes, and (2) stimulating the development of basic scientific skills – i.e. producing *young scientists.*

The 1970s saw growing dissatisfaction with the outcomes of the reforms that started in the late 1950s. The general view was that these science curriculum reforms were ineffective. De Jong (2007) cites a number of factors that caused this, including: curricula largely ignored aspects of science that might touch on the lives of pupils, and science educators focused on the existing "body of knowledge" of science from the expert viewpoint, rather than from the pupil viewpoint. Curriculum designers in general did not seriously consider the interests of pupils in the "real" world, nor did they prepare pupils to discuss and deal with issues that affected their own lives.

The 1960s and 1970s was a period of marked social changes. Before the 1960s post-primary education in many countries including Ireland, was still a privileged phenomenon. Only a minority of primary school leavers progressed to post-primary level. During the 1960s, as economies grew, second level education started the change from education for the privileged, to education for the masses (Fensham, 1988). Consequently, by the early 1970s, science education faced the problem of trying to interest, and meet the needs of new groups of school pupils, the majority of whom would not proceed to third level studies. Governments in many Western countries were no longer focusing much of their attention on the space race. Rather the increasingly technological nature of society, domestic issues and environmental problems ranked high on many national agendas. It was a time when ordinary people were questioning some of the advances in science and technology. They were seeking access to information and an understanding of science to enable them to comprehend the effects, both positive and negative, of science and technology on their lives.

2.1.2 Science literacy crisis

By the early 1980s it was apparent to all that there was a second-generation crisis in science education in Western countries, particularly the US: it was labelled "the science literary crisis" (Matthews 1994 p. 29). In the late 1970s and early 1980s, reports began emerging on the state of science education. In the US a major research effort called *Project Synthesis*, funded by the National Science Foundation (NSF) in 1977 and reported by Harms and Yager (1981), indicated that the personal needs of pupils, societal needs, career awareness and academic preparation are the four major science education goals. However, this research also revealed that only the goal of academic preparation was receiving marked attention. The research also pointed out that future science curricula should help pupils to understand how science, technology and society all influence each other. Hurd (1983) described science instruction as lacking in the provision for learning by direct experience, and as being narrowly focused on the preparation for examination and the next level of science in school and/or university. Yager (1983) criticised curricula for an over-emphasis on text books as the only method of portraying science, especially at second level, and for the high academic level, and low relevancy of content. In Britain the Association of Science Education (ASE, 1979) advocated science education for *all* pupils to the age of 16 years, with a curriculum that incorporated balance between specialist and general aspects of science, reflecting science as a cultural activity.

Several studies in different countries over the last two decades of the twentieth century reported that pupil interest in science declined the longer the pupil studied science (Huefthe, Rahow & Welch 1983; Yager & Penich 1984 in Yager 1996). Most pupils elected not to study science any further after completing the minimum required for second level education. Furthermore, most pupils indicated that they would not use, nor could they see a use for, the science they had experienced in school (Yager 1983). Research on the teaching and learning of science indicated that meaningful learning in science was usually limited to a small minority of pupils.

One important factor encouraging change during the1960s and 1970s was the perceived need to expand the number of potential scientists and engineers. As a result, curricula were developed that targeted the “brighter” pupils. As a response to this science literacy crisis, Governments and educational authorities in many countries in the western world began to produce a number of reforms. Many curricula were developed in different countries such as USA, Canada, UK and Australia which proposed the teaching of science more contextually, incorporating the ethical, historical and technological dimensions of science. A number of reform movements were established including those advocating: Scientific Literacy, Science for all, and Science Technology and Society (STS). The Science for All movement in the United States and the “Public Understanding of Science” in the United Kingdom, led to a widening of the number of pupils exposed to science in school. The STS movement was influential in the UK, the Netherlands, Canada and the USA. There was also more science on primary school curricula than ever before.

For example, in the UK, science was made a “core” subject for all pupils (aged 5 to 16) in the National Curriculum introduced in 1989. The STS movement ensured that there was some expanding of the scope of science education. STS curricula, developed in Canada and the United States (Solomon & Aikenhead, 1994; Yager, 1996), encouraged pupils to consider the social, political, economic and ethical aspects of science. Despite this, in the UK, in 1998, the significant report, *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998), concluded that the National Curriculum (at primary and post-primary) had failed to meet the requirements of a contemporary society. The report conceded that:

> the changing curricular position of science has not been accompanied by corresponding change in the *content* of the science curriculum . . . This has remained fundamentally unaltered and is, essentially, a diluted form of the 1960s GCE curriculum (p.4)

Key recommendations from *Beyond 2000* included: greater focus on scientific literacy in compulsory education; greater emphasis on technology and the applications of science; greater attention to the social processes used to generate, test and scrutinize knowledge claims; and, a wider range of teaching and learning approaches by teachers. The recommendations made in the *Beyond 2000* report led to the development of a new science curriculum for 14 to 16 year old pupils in the UK. In September 2006, a significant new science curriculum development known as *21st Century Science* was introduced into UK schools. *21st Century Science* attempts to identify the content, and the ideas about science, that are needed to function in a scientific and technological society. The curriculum contains a compulsory core concentrating on scientific literacy and additional optional components with either a "pure science" or an "applied science" emphasis.

2.1.3 The influence of educational psychology on science education

Science education reform in the last 50 years has not only been influenced by dissatisfaction with curricula, it has also been affected and shaped by several new perspectives that came from the domain of educational psychology. Science education reform in the 1960s and early 1970s was strongly influenced by behavioural psychology, especially the ideas of B. F. Skinner. The behaviourist model principally sees children in a passive role, reliant on the external environment to condition their learning; i.e. learning occurred when the appropriate outside stimulus was provided and responded to. Behaviourism in schools placed the responsibility for learning firmly on the shoulders of teachers.

The latter part of the 20th century saw the cognitive sciences provide new insights into human learning. Theories and ways of thinking about education not only changed, but underwent a paradigm shift in how education and learning were viewed. The works of educational psychologists such as Piaget and Bruner contributed in decisive ways to our understanding of children's cognitive development. One of Piaget's enduring contributions was that through continuous interaction with their environment, children shape their own ideas of reality. Bruner's theoretical framework, also widely influential, is founded on the premise that learning is an active process wherein learners form new ideas and concepts drawing on their past knowledge.

There has been an upsurge of interest within science education in "children as learners", especially in the "constructivist" view of learning. However it is important to stress that constructivism is not a new concept. As a philosophy of learning it can be traced back to the work of John Dewey in the early 20th century. Dewey's philosophy of education focused on learning by doing. He rejected the notion of rote memorization and dogmatic instruction. Dewey called for education to be grounded in real experience. The constructivist view of learning sees children as learners who construct and reconstruct their own meaning in the light of their experiences, rather than mainly acquiring knowledge from other sources. The learners make sense of their experiences by drawing on their pre-existing knowledge and beliefs. Driver and Bell (1986, pp. 453-454) summarised the constructivist view of learning in the following way:

1. Learning outcomes not only rely on the learning context but also on the knowledge of the learner;
2. Learning includes the creation of new meanings. Meanings formed by the pupils from what they see or hear may not be those expected. Creation of a meaning is influenced to a great extent by existing knowledge;
3. The construction of meaning is a ongoing and active process;
4. Meanings once constructed, are assessed and can be accepted or discarded;
5. Learners have the final responsibility for their learning.

Constructivism is a spectrum of views. Matthews (1997) states:

> The following domains need to be separated and independently appraised: Constructivism as a theory of cognition, of learning, of teaching, of education, of personal beliefs, of scientific knowledge, of ethics and politics, and finally constructivism as a worldview. (pp 492-493)

Within educational contexts there are several philosophical meanings of constructivism, including: personal constructivism as depicted by Piaget, social constructivism defined by Vygtotsky, and radical constructivism as promoted by Von Glasersfeld. A common theme running across all definitions is the constructivist view of learning, the notion that knowledge is not passively received by the learner, rather it is actively built up by them. Constructivism in its various forms is a major influence on research and curriculum development in science education. Fensham (1992) states "the most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning" (p. 801). However, the wide acceptance of constructivism in science education does not mean that its position has gone unchallenged, or that it has been universally accepted by science teachers (e.g. Osborne, J., 1996; Matthews, 1998). There is a strong challenge to constructivism. This can be found in articles by Matthews, Nola, Phillips, and Ogborn in a special issue of the journal *Science & Education* in 1997 titled "Philosophy and Constructivism in Science Education". The articles are also available in Matthews (1998). Coll and Taylor (2001) stress that the criticisms of constructivism in the literature can be largely categorised as concerns with the theoretical and philosophical aspects, especially its epistemology. Matthews (1998) states that, "constructivism" is often treated as a package deal, by advocates and critics alike, where commitment to a certain approach to learning automatically commits one to a theory of teaching, a view of epistemology, a conception of reality, and so on. Burbules (2000, p. 2) claims "constructivism" refers to many ideas, joined by the merest thread of family resemblance and often expressing quite contradictory views.

Teachers do not need to embrace all components of constructivism e.g. that all of reality is nothing but a social construction, in order to enhance innovative teaching and learning. An appropriate pragmatic approach concerning pedagogy is more imperative than adherence to any particular philosophical belief system. Burbules (2000, p. 12) states:

> constructivist approaches to pedagogy would be generally better off if their advocates stayed out of the epistemological and metaphysical speculations that they seem unable to resist ...these broader pronouncements are neither necessary for constructivist pedagogy, nor particularly helpful to it.

Bubules (2000) argues that almost with religious fervour, the proponents of constructivist approaches deem that the entire system of education should be altered around their principles. However, effective teaching includes a multitude of techniques: lecturing, talk and chalk, project work, group work, questioning, debates, and so on. Constructivist approaches such as participatory learning, discussions and open-ended questioning are valuable, but not the only resources teachers will need. Matthews (2000, p. 18) maintains that constructivism has done a service to science education by emphasising the importance of prior learning, emphasizing the importance of understanding as a purpose of science teaching and promoting pupil engagement in lessons. Many of the principles of learning "espoused in the [Irish] Primary Science Curriculum draw indirectly on aspects of constructivist learning theory ...especially in science" (Johnston et al. 2007, p. 222). From a constructivist perspective, the present study involved elicitation of participants' previous ideas, explanations of these ideas, exchange of ideas with colleagues, and development of new ideas, followed by analysis of development in understanding. These were of significance because of their importance in the learning procedure: not for the reason that they were equally valid alternative views of the world.

2.2 The role of science as a subject on the primary curriculum?

Before discussing the place of primary science on the curriculum it is important to understand what the term "science" means. The Latin word for science is "scientia," meaning knowledge. However, science involves more than a body of knowledge. It is an intellectual activity carried out by humans as a means of discovering and understanding the world around us, and finding ways in which this understanding can be organized into meaningful patterns. Science tells us important things about ourselves, our environment, the universe and our place in it. Science has three main aspects:

> (a) a body of knowledge – being scientific involves the development of concepts and using concepts and theories to try to explain phenomena and experiences;
>
> (b) a set of methodological approaches – scientists find out about the world using basic skills and processes, such as observation, classification, hypothesising, data collection, interpretation of data and evaluation;
>
> (c) attitudes – science can help in developing a child's character. Attitudes such as: curiosity, respect for evidence, creativity, open-mindedness, co-operation with others, critical reflection and perseverance can be achieved through hands-on, child centred investigations.

Johnston (1996) sees the development of science as a "triple helix" of conceptual knowledge, skills and attitudes all developing together to support later understanding.

Educational, social, political and economic justifications can be put forward when making a case for teaching science to all pupils, from primary school right up to the end of compulsory secondary school. Fensham (2002) states "science as a component part of compulsory school education is, in one sense, so obviously necessary that it requires no more statement of purpose than its title" (Fensham 2002, p. 208). Research (Driver, 1983; Osborne and Simon, 1996; Harlen and Qualter, 2007; Rocard, 2007) shows that introducing science to the primary school curriculum can contribute to: (a) preparing well rounded, clear thinking *scientifically literate* citizens to enter the workforce, and pursue careers; (b) preparing pupils to study science at third level, producing a steady stream of scientists who will contribute to the economic and social well-being of the country, and; (c) developing children's cognitive and process skills - encouraging children's innate inquisitiveness about the world and helping them to cultivate a more scientific understanding of their world.

2.2.1 Scientific literacy

According to a European Union published report (Rocard et al. 2007) on concerns about the declining interest of young people in science education, a fundamental purpose of school science is to promote scientific literacy:

> There is obviously a need to prepare young people for a future that will require good scientific knowledge and an understanding of technology. Science literacy is important for understanding environmental, medical, economic and other issues that confront modern societies, which rely heavily on technological and scientific advances of increasing complexity (p. 6).

In Ireland the Task Force on the Physical Sciences (2002, referred to in more detail below) argues that, "in an era of rapid technological change, the goal of "scientific literacy for all" has become a primary objective of general education" (2002, p. i).

Over the last three decades, scientific literacy has become an internationally accepted educational goal. Many educationalists (Champagne 1989; Bybee 1991; Millar & Osborne 1998) describe scientific literacy as the main purpose of science education. In their report, *Beyond 2000: Science Education for the Future*, Millar and Osborne (1998) propose that "the primary and explicit aim of the 5-16 science curricula should be to provide a course which can enhance "scientific literacy" as this is necessary for all young people growing up in our society, whatever their career aspirations or attitudes" (p. 9). They suggest that school science education must aspire to create a general population who are at ease, proficient and confident with science and technology.

> The science curriculum should provide sufficient scientific knowledge and understanding to enable pupils to read simple newspaper articles

> about science, and to follow TV programmes on new advances in science with interest. Such an education should enable them to express an opinion on important social and ethical issues with which they will increasingly be confronted (p. 9).

Definitions of scientific literacy vary, but for many the concept implies a broad and working understanding of science. The definition provided in USA Project 2061 captures many of the features of scientific literacy:

> Scientifically literate pupils are those who are familiar with the natural world and recognise its diversity and unity. They understand key concepts and have an awareness of ways in which science, mathematics, and technology depend upon one another. Scientifically literate pupils know that science, mathematics, and technology are human enterprises. They know what it can imply about science, mathematics, and technology's strengths and limitations. They have the capacity for scientific ways of thinking and use scientific knowledge and ways of thinking for individual and social purposes (AAAS, 1993).

Scientific literacy focuses on three main areas: the subject matter of science, the nature and practice of science, and the associations between science and society. Layton, Jenkins and Donnelly (1994), having examined the subject of scientific literacy, established the following contributing features to scientific and technological literacy:

(i) a body of facts, skills and concepts, the assortment of which might show some reliance on culture;

(ii) some familiarity and understanding of what it entails to work as a scientist or technologist,;

(iii) an awareness of science and technology as cultural endeavours, including the principles and assumptions which they contain. (pp. iii–iv).

These interpretations suggest that scientific literacy ought to be seen as a level of knowledge of science and technology required to work *minimally* as responsible citizens and in society. They indicate that science should be understood as an important social force, not simply as a set of abstract principles held by experts. Citizens who lack the *minimum* level of scientific literacy will not be capable of making informed decisions on a range of important areas. Thus they will not fully take part in the democratic process and will become somewhat disenfranchised. Harlen and Qualter (2007) maintain that primary school science education is imperative for the promotion of a scientifically literate society. Millar and Osborne in their significant report, *Beyond 2000*, state:

> primary science supports the curriculum priorities of literacy and numeracy, whilst adding an important dimension that would otherwise be lacking; it starts the development of young children's capability in reasoning from evidence, using clearly and precisely defined concepts and ideas. (1998, p. 4)

If we are teaching children to be linguistically and numerically literate in primary school, surely, it is the ideal environment to begin to teach children to be scientifically literate.

2.2.2 Economic and social well being

The Rocard Report (2007) claims it is irrefutable that a high quality scientific and technical workforce is essential for the social and economic well-being of a technological society. Underpinning international competitiveness is the need for a constant supply of scientists, engineers, and technically skilled workforce: "Availability of highly qualified science and technology professionals is a key factor for the establishment, import and success of high-tech industry in the European Union" (p. 6). Osborne et al. (2003) ascertain that "there is a clear association between economic performance and the number of engineers and scientists produced by a society" (2003, p. 1053).

As the Irish economy is increasingly becoming more "knowledge-based" the quality of our workforce is being seen more and more as the most significant economic benefit of our society. According to the Government Report: *Building Ireland's Knowledge Economy – The Irish Action Plan for Promoting Investment in R&D to 2010* (2004), the Government's stated purpose is the development of Ireland as a knowledge economy – increasing employment, wealth creation and social well-being, in an increasingly competitive global society. The importance of science in developing and sustaining Irelands' economic growth and career opportunities has been acknowledged by former Taoiseach Mr Bertie Ahern T.D. He stated:

> People are at the heart of the knowledge society. Success in the future will be strongly dependent on growing the skills of our population and

> ensuring that levels of scientific and mathematical literacy increase. This places new demands on our education system, from primary level upwards. (*Strategy for Science, Technology and Innovation Report 2006, page i)*

From the early 1990s, Ireland's economy "Celtic Tiger" grew to be one of the most vibrant in Europe (Childs, 2002). Its success in attracting high-tech multinational companies in pharmaceuticals, biotechnology and information technology proved the cornerstone of the economic success of those years. Ireland's main competitive advantage for attracting this type of multinational has come from the availability of a well-educated workforce. Childs (2002) argues that if we want to ensure the continued investment of "high-tech" industries in Ireland it is of paramount importance that the Irish workforce is up-skilled and that there is a sufficient number of graduates skilled in the fields of science and technology. However, he also stresses that the number of pupils studying the physical sciences in Ireland has been a cause for disquiet for some time. The *Strategy for Science, Technology and Innovation Report* (2006, p. 51) reveals that, 14.7% of the Leaving Certificate pupils study physics and 13.6% study chemistry. It also shows that the numbers taking these subjects has fallen off significantly since the 1980s, and even though the descending trend has been stopped, there is a crucial need to increase the number of pupils taking up of these subjects in the upcoming years. There is unease concerning the numbers of pupils pursuing science options at third level. Over the last decade, this decline in numbers studying science has received much attention at academic and political levels. In 2005 the Royal Irish Academy (RIA) invited prominent scientists and academics to a series of workshops. The Workshops, entitled "School Science Infrastructure: Can Ireland Deliver?" arose from serious concerns voiced by many in the Irish scientific community for some years, concerning the decreasing uptake of physical science subjects post-compulsory education. Recommendations from the workshops (p. 7) included:

- the need for a revised education policy, one that aims to achieve a scientifically literate society;
- a clear development of science education from primary and throughout second level, with a logical progression from the Junior Certificate curriculum to the Leaving Certificate curriculum;

- the revision of Leaving Certificate syllabi in Chemistry and Physics, with the implementation of practical examinations at the earliest possible opportunity and with a greater emphasis on more STS (Science-Technology- Society).

Politically, successive governments have tried to address this issue by producing several documents and carrying out a number of initiatives. Several Government documents including: *The White Paper on Science Technology and Innovation* (1996), *Report of the Joint Oireachtas Committee on Education and Science on Science and Technology* (2000), and *the Strategy for Science, Technology and Innovation 2006-2013*, have highlighted what they have regarded as the importance of science education as our most important competitive advantage to continued growth in our economy. In 2000, the then Minister of Education and Science, Dr. Michael Woods, established a Task Force on the Physical Sciences. The main goals of the Task Force were: to tackle the issue of low take-up rates of science subjects at post-compulsory education, and examine the obstacles to pupils choosing physical science subjects at post-primary level and third level. The Task Force published its report in 2002. It stated "Ireland's economic future depends critically on the supply of an increasing number of people qualified in science and engineering" (p. i). The Irish Council for Science Technology and Innovation (ICSTI) was created in 1997. One of its key aims was to examine ways of promoting innovation in science and technology and to recommend policy to the Irish government. In 2006 the government appointed Dr Barry McSweeney as its first Chief Science Advisor and established a Cabinet committee on science.

Research by Murphy and Beggs (2003) shows that children's attitudes towards science form early and these tend to peak at age 11 (Osborne et al., 1998) before they reach the end of primary school. When introducing the primary science curriculum in 2003 the government recognised the importance of primary schooling in arousing an interest in science.

> As well as helping children to become scientifically literate members of society, the curriculum aims to foster positive attitudes to science and to encourage pupils to develop an appreciation of the contribution of science and technology to society... promote curiosity and enjoyment, so that the pupils develop a lasting interest in science... (DES, 1999b, p. 3)

The younger children are when they experience science in school, the more likely they are to develop positive attitudes towards science (Murphy and Beggs, 2003). The hope is that by targeting younger children they will bring a love and curiosity for science with them throughout their life.

2.2.3 Educational benefits to studying science

This section will be a review of the educational arguments that are advanced for expanding science education in primary schools, as distinct from the social and economic policy arguments that have been reviewed in the previous section.

The argument made on educational grounds would run along the following lines: science learning does not start with formal science lessons in school - it starts long before that in the home and continues into playschool. Children are interested in practically everything that occurs around them, scientific activities are fascinating to children and can involve them in exploration and "finding out" for themselves. Harlen and Qualter (2007) stress that primary science education can harness young children's natural curiosity, give them a structure for understanding the world around them, and provide them with opportunities to manipulate materials, ask questions, hypothesise, predict and test their predictions. Such opportunities give children the chance to ask how and why certain things happen in the world around them.

Miller and Osborne offer an important insight here:

> Science deals with major themes in which most people are already interested: life and living things, matter, the Universe, information, the 'made world'. A primary reason for teaching science to young people is to pass on to them some of this knowledge about the material world, simply because it is both interesting and important (Millar & Osborne 1998a p. 2007)

Science, with its focus on enquiry and objectivity, provides a unique contribution to the cognitive development of young people. Primary science can present children with a chance to understand more about their material world, developing cognitive and scientific skills to discover for themselves, to ask questions and seek answers to those questions. As Black (1993) points out, a central goal of science education is its contribution to the general intellectual growth of the pupils. Science education offers young children opportunities to develop critical and creative thinking skills such as: interpreting data and suggesting patterns to explain data, and to learn how to learn from experience. Solomon (1995) argues that the rationale for learning science is to obtain scientific ways of explaining phenomena – primary science can help children obtain process skills including: questioning, planning, observing, predicting, measuring, communicating and evaluating i.e. skills essential for successful investigation of the questions and problems in science. The benefit to a child's development through science in primary school is not only to be justified in terms of intrinsic usefulness, but also in terms of its positive effects on other subjects and areas of learning. Research by Kepler (1996) maintains that children who are taught science in primary school learn things that can be used in other subjects on the curriculum. For example, science can help pupils develop their oral skills, writing skills, ICT skills, reading skills and numerical skills.

Research suggests that children come to school with their own ideas of science. They continue to develop these ideas whether or not they are taught science; many of these ideas are intuitive and unscientific. Two projects; the Learning in Science Project (LISP) in New Zealand (Osborne and Freyberg, 1985) and Science Processes and Concept Exploration (SPACE) in the UK (1987–1992), have had a major influence on increasing our awareness of the significance of primary school pupils' preconceived ideas of their world.

The Science Processes and Concept Exploration (SPACE) research was a classroom–based study that investigated the ideas that primary school pupils previously held in science. The project recognised, and most importantly valued children's ideas. It also explored, whether the children could be supported to change their ideas following appropriate experiences (Osborne, Wadsworth, Black & Meadows, 1994). Findings from SPACE found that the pupils do have prior ideas about their world, and many of their explanations are not always very scientific. The research also concluded that teachers could assist their pupils in developing their ideas into more scientifically accepted forms (Osborne, et al., 1994).

Harlen (2001) claims "results from these two extensive reports were remarkably consistent with each other and with other later studies conducted in countries across the world" (p. 61).

Key research findings from the LISP and SPACE projects included:

- Children's ideas are often different from scientific ideas used by their teachers;

- Children approach science topics with strongly held ideas of their own – not with empty minds to be filled;
- Science lessons in secondary school often leave children's own ideas untouched; as a result it has little impact on them.

This research indicates that the ideas that children develop are as a result of thinking and reasoning and they make sense to the children. However, many of these ideas may be non-scientific i.e. may not reflect the ideas that scientists themselves hold. Because these ideas are different from the accepted scientific ideas they have been called "misconceptions" or "alternative conceptions" (Driver, 1983). If pupils are not taught science during these years i.e. given guidance to test out their ideas' and consider alternatives; they could persist and develop in a haphazard way. The children may take their "misconceptions" from primary school into secondary school, increasing the possibility of second level pupils finding science confusing and difficult. Such misconceptions may disrupt or impede the development of science at secondary school. With careful support in primary school "children's misconceptions" could be changed into more scientific ones i.e. they could build up ideas that will help rather than impede later learning in science. This can be achieved by engaging children in testing and explaining their ideas through scientific investigation. This is perhaps one of the most powerful reasons for including science in the primary curriculum.

From the researcher's teaching experience, a strong justification for teaching primary science is seeing, the faces of children lighting up while they are carrying out their own investigations; the intensity of their involvement in their task; and their sheer delight as they make their own discoveries.

2.3 Summary

Over the last half-century there have been several challenges to the nature of science education; economic, societal and how children learn. These have led to reforms, or at least a change of emphasis, in school science in some western developed countries. Research mentioned in section 2.2.3 shows that science in primary school can benefit children as individuals by promoting the development of:

- skills needed to understand their environment;
- attitudes such as inquisitiveness, which guides their learning;

- concepts and subject matter that assist them in understanding the world around them.

Introducing science in primary school can benefit society. It plays an important role in developing two of the most widely recognised qualities needed by future citizens: providing a good basis for lifelong education, and scientific literacy. However, research on enhancing the teaching and learning of primary science claims that if this is to be achieved, primary science needs to be experienced as an engaging, valuable and interesting subject in its own right. In meeting this challenge, educators need to engage pupils in a process which:

- Relates science to the everyday life of the pupil and to the society in which the pupil lives;
- Enhances the personal development of pupils and contributes to their lives as citizens;
- Takes into account the thoughts, diverse needs and feelings of the pupils. Pupils differ in many ways other than cognitive ability; they have different ways of working; they are motivated by different teaching strategies, and they have different aspirations and goals.

This will require teachers who are confident and competent in teaching science, who have positive attitudes towards science, and who have access to productive continuing professional development. These issues will be investigated in more detail in the literature reviews in Chapters Four and Five.

Chapter 3
Key Issues Relating to the Role of Primary Science in Ireland

Introduction

The purpose of this chapter is twofold, firstly from a historical perspective it briefly examines the development of the primary science curriculum in Ireland – exploring the rationale given for attempting at various times to insert and remove science from the curriculum, concluding in its inclusion in the 1999 revised Primary School Curriculum. Secondly, it examines the implementation of the 1999 curriculum (DES, 1999) and the support in the form of professional development provided during its implementation. It also analyses the relevant research both nationally and internationally regarding a number of concerns facing the implementation of science in Irish primary schools. The first part (section 3.1) gives a chronological account of the position and development of science in Irish primary schools and briefly explores its chequered history since the 1800s as well as the impact of this on the development of the primary science curriculum. The second part (section 3.2) examines: the intentions, emphases, content and skills of the revised Primary Science Curriculum of 1999, and outlines a number of initiatives and supports introduced to assist in its implementation. Part three, (section 3.3) probes some of the concerns regarding the implementation of the science curriculum in Irish primary schools. The fourth part (section 3.4) investigates international findings regarding the implementation and development of primary science in other countries. The chapter concludes with a summary drawing on the historical and recent developments in Irelands' primary science education (section 3.5).

3.1 Overview of primary science education in Ireland past and present

Over the past two centuries the place of science on the Irish primary school curriculum has been influenced by national and international economic and political conditions. This has resulted in science being added and removed from the primary curriculum on several occasions.

3.1.1 Primary science pre - 1900

During the early nineteenth century, science was introduced for the first time into the school curriculum in primary schools. This development coincided with the high tide of the industrial revolution in Europe, reflecting concerns that economic development in the United Kingdom (including Ireland at that time) could not occur without a scientifically and technically trained workforce. In the Irish context in particular, an understanding of elementary science was thought essential to improve agriculture. As far back as 1813 the Society for the Education of the Poor in Ireland produced a mechanics' course in their Kildare Place Society schools; they even produced a set of text-books in mechanics, one of the first set of text-books ever produced in Ireland. In the early 1830s, science, in the form of agriculture was promoted as a subject for study by the Commissioners of National Education. The Board of Commissioners was established by the UK administration in Dublin in 1831, succeeding the Society for the Education of the Poor in Ireland. The Commissioners believed that the promotion of better agriculture could cure many of the country's problems. Beggan states:

> The Commissioners believed the principal cause of wretchedness, want and starvation in Ireland was attributable to the gross ignorance of the labouring classes of the best modes of agriculture and of the rural economy. (Beggan 1988, p.36).

The Commissioners believed that schools under their charge should produce an "intelligent class of farm labourers and servants" (Beggan 1988, p 37). In 1872, agricultural education was made compulsory in the senior classes of every "rural boys" school. In 1885, agriculture was made compulsory in all rural national schools for boys in fourth and higher classes, and was optional for girls.

The encouragement of science (as we know it today), as distinct from agriculture, in national schools dates from 1855. This was a political decision generated by the realisation that industrial development in the United Kingdom, including Ireland, lagged behind that of other European countries. However, this drive was not very successful in Ireland, and by the end of the 19th century elementary science was taught only in a very small number of schools. One major reason for this was the introduction of "payment by results" for teachers in national schools in 1872. The payment by results system in Ireland shaped the method of instruction to the extent that any subject not coming under this umbrella was not taught. It accelerated the drive towards the 3Rs and sought to make teachers more accountable (Coolahan, 1981, p. 7). Optional subjects, for which results fees were claimed, such as science, had to be taught outside the normal school time, before or after ordinary school hours (Quane 1998, p. 44). Preparation for science lessons is time consuming, and under the results system, teachers were not financially rewarded for this time. As a consequence, many of them did not teach science.

3.1.2 Primary science 1900 - 1922

In 1897, the Commission on Manual and Practical Instruction (also known as the Belmore Commission) was created to redress the bias towards academic subjects in Irish primary education. It carried out a comprehensive review of contemporary developments in curricula, both nationally and internationally. Coolahan points out, “it concluded the Irish system with its narrow concentration on a three Rs-type curriculum was out of date and needed fundamental reform” (Coolahan, 1981, p. 34).

In 1900, the Revised Programme was implemented. This innovative programme put an end to the system of “payment by results” formerly in operation. An expanded curriculum was introduced, including subjects such as Manual Instruction, Drawing, Singing, Cookery, and Physical Drill. As well as a radical modification in subject matter, the methodology was also changed from that of a didactic and subject-driven style, to a heuristic and child-centred approach. Elementary Science was made compulsory, and four modules were introduced: experimental science, agriculture, light and sound, and magnetism and electricity. Mr William Heller was appointed Head Organiser of Science in Ireland. Heller was a devotee of the renowned English science educator Henry Armstrong, a highly influential advocate of the “discovery method” in science education. Heller trained national teachers and encouraged them to take a practical approach to the teaching of science in Irish national schools. Beggan comments:

> the purpose of primary science, as put into effect by Heller and the National Board, was to give pupils ample experience of the scientific method of inquiry, to teach self-reliance in work, to cultivate accurate observation and accuracy of thinking and verbal expression (Beggan 1988, p.44).

The Revised Programme of 1900 was progressive and enlightened in its philosophy – benefitting from a wide and varied curriculum. The new heuristic and discovery-like methods of teaching put children at the core of the educational process (Walsh, 2007, p.138). According to Walsh (p. 140) “the language and content of the Revised Programme is re-echoed in later curricula in Ireland, including the current Revised Primary Curriculum (DES 1999)”. However, the 1900 programme proved largely ineffectual. It lacked a tactical implementation policy tempered to the public and educational context of the day (Walsh, 2007, p. 141). Underlying obstacles included the lack of sufficient resources, financial and intellectual. Teachers felt the demands of the programme were impractical under the prevailing circumstances (Coolahan, 1981, p. 35). Practical subjects, such as elementary science which required equipment, were generally only taught in large urban schools. Many of these challenges and obstacles concerning the curriculum implementation are still significant to curriculum implementation today.

> As the historical perspective teaches us, curriculum development is a continuum, of which devising the curriculum is but an initial step. Of far greater importance and complexity is its implementation, which will not be successful without concerted action and support at national and individual level (Walsh, 2007, p. 141).

3.1.3 Primary science 1922 - 1971

During the last decades of the 19th century and the early years of the 20th century, the influence of cultural nationalism became apparent in many European countries, including Ireland. Quane (1998) states “there was considerable support for the ‘Gaelicisation’ of Ireland which should and could be achieved through its education system” (p. 72). In 1921, a quite different programme for National Schools was prepared by the National Programme Conference under the authority of Dáil Éireann, and was introduced into National Schools in 1922. It brought in a more restricted curriculum than the one previously in place. The main impetus of the programme was its emphasis on Irish language, history and tradition. This programme set the general pattern and tone of Irish national education for a period of nearly fifty years (Coolahan, 1981, p.41). Elementary science and other practically based subjects were removed as compulsory subjects. These became optional subjects and were only offered to schools that had suitably equipped laboratories and/or gardens.

Because of problems with the implementation of the 1922 Programme, a Second National Programme Conference was convened in 1925. In 1926, elementary science in the form of nature studies was added to the list of compulsory subjects for certain categories of schools (National Programme Conference, 1926). The syllabus included topics such as matter, water, plant and animal life and food. The practical aspects of the subject were to be emphasised in order “to supply a concrete medium for the general development of the intellect and the character of the pupils and which, at the same time, will bring their education into relationship with their lives and surroundings" (Department of Education, 1926, p. 43).

In 1932, Fainna Fáil came to power for the first time. The new Minister for Education, Mr. Thomas Derrig, announced he was committed to a school programme which fostered a patriotic and Gaelic culture and was prepared to lighten other aspects of the programme to achieve this (Coolahan 1981, p. 42). In 1934, the Government pruned back the primary curriculum in an effort to further promote the "teaching of Irish" in primary schools. Again elementary science became an optional subject, making way "for more rapid progress and more effective work in the teaching of Irish and in the development of teaching through Irish" (DoE 1934 p.3 cited in Matthews, 1992, p.7). Deeply unhappy with the state of affairs in Irish primary schools in 1947 the Irish National Teachers Organisation (INTO) published *A Plan for Education*. This proposed a more child-centred school programme and a wider number of subjects on the curriculum. The INTO urged the introduction of primary science to "introduce young people to the method of objective investigation....and awaken an intelligent interest in the physical environment" (INTO, 1947, p. 51). However, their proposals were not adopted, and the 1922 Programme remained in place until 1971. Beggan (1984) claims the neglect of science during this period impacted on the advancement of the material welfare of the country and was a "poor foundation on which to build a modern industrial society" (p. 18). Unlike the Revised Programme of 1900 which emphasised a child-centred approach to education, the 1922 Programme relegated the needs and interests of the child to accommodate the revival of the Irish language.

3.1.4 Primary science 1971 – 1999

The economic boom across Europe (including Ireland) in the 1960s initiated a dramatic increase in investment and interest in education. Education was now officially seen as an "economic investment as distinct from the traditional view of education as a consumer service" (Coolahan, 1981, p. 131). There was a growing awareness of the need to invest in education for Ireland to participate on an increasingly international stage. Increased links with international organisations such as the United Nations (UN), United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the Organisation for Economic Co-operation and Development (OECD) helped to break down the insulation that had characterised Irish educational policy since the 1920s.

During the late 1960s, the Inspectorate of the Department of Education drew up a new curriculum for primary schools. This curriculum was introduced into schools in 1971 (Department of Education, 1971). The 1971 curriculum based on the ideology of child-centred education, content and format, was a radical contrast to that which had existed previously (Coolahan, 1981, p. 135).

> Influenced by Piagetian constructivism, the 1971 curriculum emphasised the centrality of the child to the learning process and endorsed the ideas of discovery learning (Waldron et al. IASSEE Report 2009, p. 11)

Nature study regained its compulsory status in the 1971 curriculum; it was included as an essential part of the new Social and Environmental studies programme for primary schools (DoE 1971). The Social and Environmental studies programme for fifth and sixth classes also included elementary science alongside plant and animal life and the environment. The primary programme advocated a process approach to science, with observation and recording forming an integral part of the process (DoE, 1971, p. 78). However, despite its initial promise, a lack of equipment, pedagogical materials, and in-service support resulted in a degree of dissatisfaction among teachers and serious under-implementation of the curriculum (NCCA, 1990; INTO, 1992). A report by the Department of Education (DoE, 1983), based on nationwide data from teachers and inspectors, stated that the 1971 curriculum, despite notable progress in other areas, had failed to encourage and promote the teaching of science in primary schools. The report (pp. 14-17) revealed that:

- Teachers did not use the discovery methods when teaching science;
- Teaching strategies were primarily didactic and prescriptive;
- Majority of teachers of middle and senior classes considered science the most difficult aspect of the Social and Environmental studies programme;
- Majority of teachers of middle and senior classes did not include science as an aspect of their respective curricula.

A survey carried out by the Irish National Teachers' Organisation (INTO) in 1987 showed that 87% of teachers questioned had 'nature' tables in their classrooms. However, only 30% reported that their pupils had carried out simple scientific experiments (INTO, 1987). In 1990, the National Council for Curriculum and

Assessment (NCCA) reviewed the 1971 primary curriculum. Its subsequent report (Quinlan Report) revealed the lack of emphasis on basic science in middle and senior classes and the apparent lack of confidence on the teachers' part in teaching it (NCCA, 1990). It also recommended that "provision be made for appropriate in-service courses" (NCCA 1990, p. 56). The provision of in-service education was reiterated by an INTO report in 1992 when it stated that "the transmission of new science programmes will have only minimal impact unless they are accompanied by a genuine commitment to promote in-service education for all teachers" (INTO, 1992, p. 46). The report also found that "while nature tables were often present in classrooms, there was little emphasis on science. The development of a suitable primary curriculum with a balance between content process and an appropriate pedagogy was seen as necessary" (INTO, 1992, p. 9). This enduring lack of emphasis on primary science in the schools was reflected in the performance of Irish children in international testing studies. The International Assessment of Educational Progress Report (IAEP 1988) recognised the shortcomings of the Irish primary curriculum as it related to science, and documents teachers lack of confidence in teaching science (pp. 54-56). It also revealed that Irish children aged 9 and 13 performed less well in science activities than their counterparts in 12 other countries, including the United States and the United Kingdom. In 1997 the Third International Mathematics and Science Study (TIMSS, 1997) showed that:

- Irish girls (age 9) had the lowest average Science proficiency score of any group in the study (p. 36);
- Only 5% of Irish primary teachers in the study used group work as a teaching strategy in most or all of their science lessons (p. 146).

A number of initiatives were undertaken to address these concerns. At primary level, the first official primary science curriculum for all children in primary school was introduced in 1999 - with full implementation from September 2003 (Department of Education 1999a).

3.2 Primary science 1999 – present

In the early 1990s, the National Council of Curriculum and Assessment (NCCA) began the process of developing a new primary curriculum, using the child-centred 1971 curriculum as a base from which to start. The Education Act 1998 gave more voice to teachers in the development of Ireland's school curriculum. For the first time in the history of the state, curriculum development involved all the interested parties in primary education, including: Department of Education, National Parents Council, Boards of Management, religious orders, and practicing teachers. This was a significant departure from previous tradition, whereby curriculum and policy was mostly decided by the Department of Education. For example, the committee set up to develop the Social, Environmental and Scientific Education curriculum consisted of: thirteen members from teacher organisations, six from religious organisations, four from government organisations and three from parent organisations (DES, 1999a, p. 121). The new Primary School Curriculum (DES, 1999) sought to cultivate all aspects of the child's life – "spiritual, moral, cognitive, emotional, imaginative, aesthetic, social and physical" (Department of Education 1999, p. 6). The fundamental principles of the curriculum were founded on the theories of child development and how children learn, including those of Piaget, Bruner and Vygotsky. The curriculum recognises that children learn in different ways, and advocates the use of a variety of teaching methodologies to increase children's enjoyment of learning and desire to learn. The revised curriculum aims to: (a) present all children with learning opportunities that acknowledge and celebrate their uniqueness; (b) develop all children to their full potential, and (c) prepare all children for further education and lifelong learning (Department of Education, 1999a, p. 7).

The revised curriculum includes science as a compulsory subject on the syllabus for all primary school pupils, from junior infants through to sixth class. It supports children in leaning about physical and biological aspects of the world, expanding pupils' knowledge and understanding through the skills of working scientifically, and design-and-make (DES, 1999a). It embraces the development of concepts, skills and attitudes, which are to be promoted simultaneously. Scientific concepts are presented in four broad strands which identify wide ranging areas of scientific knowledge and understanding (a) living things, (b) energy and forces, (c) materials, and (d) environmental awareness and care. All four areas are further divided into strand units as shown in table 3.1 below.

As well as acquiring knowledge, children are expected to develop a number of scientific skills and design-and-make skills (technology) during their primary school years. Scientific skills include: questioning, observing, predicting, investigating, analysing and recording. Design-and-make skills include: exploring, planning, making and evaluating.

Table 3.1: Primary Science Strands and Strand Units

	Infant classes	**1st & 2nd Class**	**3rd & 4th Class**	**5th & 6th Class**
Living things	Myself Plants & Animals	Myself Plants & Animals	Human life Plants & Animals	Human life Plants & Animals
Energy & Forces	Light Sound Heat Forces Electricity & Magnetism	Light Sound Heat Forces Electricity & Magnetism	Light Sound Heat Forces Electricity & Magnetism	Light Sound Heat Forces Electricity & Magnetism
Materials	Properties & characteristics of materials Materials & change	Properties & characteristics of materials Materials & change	Properties & characteristics of materials Materials & change	Properties & characteristics of materials Materials & change
Environmental awareness & care	Caring for myself and my locality	Caring for myself and my locality	Environmental awareness Science & the environment Caring for the environment	Environmental awareness Science & the environment Caring for the environment

The teacher guidelines for the science curriculum encourage the employment of a variety of teaching approaches and methodologies in order to promote positive attitudes towards science. It recommends starting from the children's prior ideas and experiences: "children's ideas are the starting point for science activities" (DES, 1999b p. 52). It also provides opportunities for these ideas to be tested, reflecting on the change in the children's ideas or development skills as well as encouraging them to develop their scientific understanding (DES, 1999b, p. 3). There is also a strong emphasis on 'hands-on' classroom science, with increased pupil practical work and a more exploratory approach to teaching and learning. The key aims of the 1999 Primary Science Curriculum are outlined below:

- 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 understand the contribution of science and technology to the social, economic, cultural and other aspects of society;
- Facilitate the child to communicate ideas, present work and present findings using a variety of media; and
- Encourage the child to behave responsibly to protect, improve and cherish the environment (p. 11).

These aims were particularly welcomed by the Irish Council of Science Technology and Innovation (ICSTI, 1998) who argue that good educational practice shows clearly that science education at primary level is not mainly, or to any large degree, about learning the laws, theories and principles of science. Primary science education, according to the ICSTI, should "aim to develop pupils' curiosity, their capacity for observation, and their analytic and problem-solving skills" (p. 2).

Research by Johnston et al. (2007, p. 222), which draws on data from a large scale national evaluation of the implementation of the Primary School Curriculum, maintains that many of the principles adopted by the 1999 curriculum draw indirectly on aspects of constructivist theories of learning. Furthermore, they stress this link is visibly highlighted in certain subjects such as science – where inquiry-based, open-ended investigations and children's ideas are made a starting point to a lesson. Change to incorporate these constructivist approaches to learning, as well as the implementation of a completely new subject, are major challenges to the capabilities of teachers, who find that important changes are called for in their classroom practice.

> Attempting to introduce a curriculum built, in part, around constructivist values, which are then enacted by practitioners who, by virtue of their own training, beliefs and practices, have other frameworks, may make implementation problematic. (Johnston et al., 2007, p. 222)

The implementation of the Primary School Curriculum has been assisted by a government-led programme of support – Primary Curriculum Support Programme (PCSP) (Department of Education, 1999c). In 2003, the PCSP provided teachers with three curriculum days (in-service) specifically for science. The PCSP will be discussed in detail in the next section. In 2004, the government, through its semi-state body *Forfás,* introduced the *Discover Primary Science* programme. *Discover Primary Science* provides in-service training days and resources for teachers and their pupils – it aims to make science fun through hands-on activities. It also provides a website for teachers and pupils. A number of organisations have provided teachers with various initiatives to develop primary science in their schools. *An Taisce* promotes the Green Schools Project – an environmental education programme – and an awards scheme promoting positive school action towards the environment. There are many other useful initiatives from parties such as: the Royal College of Surgeons Dublin, REMEDI Ireland (Regenerative Medical Institute), STEPS (Science, Technology, and Engineering Programme for Schools) and Sustainable Energy Ireland, all providing courses and resources for teachers and pupils - encouraging them to develop their scientific knowledge and skills.

This support marks a significant improvement in recent years. However, there are some suggestions among educators that this support is not enough (NCCA, 2008; Varley et al. 2008). Personal anecdotal conversations with practising primary teachers have revealed that many of them (especially older teachers) don't feel confident and/or competent in teaching science. It should also be noted that many primary teachers qualified as teachers in a time where primary science, as we now know it, did not exist for them and many of them have little in the way of science qualifications. Teacher professional development is a precondition to the effective implementation of the Primary Science Curriculum. As already noted, the powerful Irish National Teachers' Organisation insists that "primary science will only have minimal impact unless it is accompanied by a genuine commitment to provide appropriate in-service to all teachers" (INTO, 1992, p. 46). They go on to state that "how in-service is to be delivered will be of critical importance in determining how Science Education is to be taught effectively" (p. 46). Matthews (1993, p. 45) warns: "appropriate, long term, in-service education will be a critical factor in determining the success, or failure, of developing science in National Schools. Especially, National School teachers will not develop their expertise by attending short one day in-service days".

3.2.1 Implementation of primary science in Irish schools

Since the introduction of the revised Primary Curriculum (1999) provision for professional development by the DES at primary level has focused almost exclusively on curricular initiatives. A support service, the Primary Curriculum Support Service (PCSP) was established in 1998, a year before the curriculum was published. During the implementation, the PCSP worked directly with the network of Education Centres. The principal professional development instruments used included in-service workshops, school-based planning days and an internet website. The prevailing structure used by the PCSP has been the secondment of primary teachers as "trainers" to assist the implementation of the Primary School Curriculum. In relation to science, in-service courses in the form of curriculum days (3 in all) were scheduled for all primary teachers during the 2002-3 academic year. Curriculum days consisted of a seminar followed by a workshop. Content areas covered included: electricity and magnetism; materials and change; and plants and animals. The workshops were interactive in nature – engaging teachers in hands-on investigations, web-based materials were provided for further support. In addition, in 2003 eight regionally-based Cuiditheóirí (i.e. members of a support team) were appointed to science. Their role was to provide support, specifically in science teaching and planning, to teachers in individual schools, but crucially only when requested by the school.

In 2005, a large-scale national evaluation of the Primary Curriculum Support Programme, commissioned by the DES and the NCCA, was carried out by researchers from Trinity College, Dublin (Murchan et al., 2005). The programme, new in an Irish context, received a positive welcome and backing by teachers and principals. Teachers were largely satisfied with the curriculum days and support provided by the Cuiditheóirí (p. 222). However, the evaluation also raised a number of concerns including:

- evidence to suggest that that the nature of Cuiditheóirí support "offering a relatively standardised, information-dominated form of support for schools and teachers" encourages a culture of dependency;
- evidence to suggest that teachers are not taking "ownership" of the curriculum;
- evidence showing a hierarchy of change, whereby most occurred in relation to teachers' knowledge with less evidence of change in teachers' methodologies.

(pp. 223-225)

Significantly, regarding the professional development of primary teachers, Murchan and colleagues recommend that in addition to seminar-based forms of professional development, a range of experiences targeted at enhancing teachers' classroom practice should be promoted. Ideally, schools should reflect a culture where teachers regularly enlist the support of peers to help them observe and reflect on practice. Strategies should be put in place to foster a sense of ownership of professional development amongst teachers (p. 5). Most significantly, research by Johnston et al. (2007, p.236), drawing on data from the national study, recommend that teachers need various forms of support tailored to local contexts and individual needs. To boost impact, future support for teachers needs to be sustained over time, allowing for observation of change in practice and regular provision of feedback. Furthermore, Johnston et al. argue that reflection by teachers themselves on their teaching, helped by an outside means, can encourage authentic change in practice (p. 236).

In September 2008, the Primary Curriculum Support Programme (PCSP) and School Development Planning Support (SDPS) support agencies merged, to form the Primary Professional Development Service (PPDS). The PPDS operated under the Teacher Education Section of the Department of Education and Skills, and its main work was to provide continuing professional development for primary school teachers (PPDS, 2009). In 2008, the PPDS had a team of eight regionally-based science Cuiditheóirí. However, by January 2010, this team had been reduced to three Cuiditheóirí (Cuiditheóirí returning to schools were not replaced). In 2010 the support services PPDS and other support agencies merged to form the Professional Development Service for Teachers (PDST). The number of seconded teachers on the PDST team was significantly reduced. Currently, the regionally based PDST teams are mainly concerned with literacy and numeracy issues. This has resulted in the limitation of government-supported professional development opportunities for teachers in the area of primary science for the foreseeable future.

3.3 Concerns for primary science in Irish schools

The implementation of primary science in Irish schools is still very much in its infancy when compared to other developed countries such as Australia, New Zealand, USA, Canada and the UK. There is, as yet, a small but growing body of relevant research literature concerning the implementation and progress of primary science in Irish schools. In 2006, the National Council for Curriculum and Assessment (NCCA) initiated a review of the Primary School Curriculum in the Republic of Ireland (NCCA, 2008). The review took place over a twelve month period and focused on principals', teachers', parents' and children's experiences of the Science curriculum, the Irish curriculum and the Social, Personal and Health curriculum. In total, over 1300 teachers from 200 schools responded to the *Review and Reflection Template for Teachers*. Principals and teachers from eight different schools participated in interviews as part of a school case study. The findings of the review indicated a number of concerns regarding the teaching and assessment of science. Even though over 95% of the 1,370 teachers stated they used hands-on activities, either sometimes or frequently, the findings indicated that the teachers in general found the hands-on collaborative learning aspect of the science curriculum to be quite challenging. The teachers also indicated that they had concerns with issues regarding assessment, namely, determining whether, and to what extent, their pupils had grasped or understood the scientific concepts and skills that had been taught.

At the same time, the NCCA commissioned St. Patricks' College Dublin to review the revised Primary Science Curriculum (Department of Education, 1999b). This review had two phases (Varley et al., 2008, 2009). The first phase of the review reported on children's experiences of the science curriculum and their attitudes to school science. In total, 1,050 pupils from 11 schools (third to sixth class) took part in the first phase. This report indicated that primary science in Irish schools appears to have come a long way over the past five years since its implementation in 2003: "overall children are enthusiastic about primary school science" (Varley et al., 2008, p. 8). However, it also warns that complacency at this juncture would be foolhardy. The report also raised a number of concerns including:

- The issue of teacher confidence regarding the development of their own ideas for teaching science;
- A concern that teacher-led and prescribed activities appear to be the norm in Irish primary classrooms;
- The limited opportunities pupils have to apply certain scientific skills e.g. design-and-make;
- Pupils do not have regular opportunities to engage in child-led investigations.

One of the main recommendations put forward in the report was "a comprehensive in-service support for teachers in the form of continuing professional development courses" (p. 10) – courses that incorporate more opportunities for action, reflection and in-depth treatment of themes (p. 166).

The second phase of the review reported on children's experiences (1st year post-primary pupils) of the science curriculum and their attitudes to school science. In total, 265 pupils from 15 post-primary schools took part in the second phase. Findings from this report highlighted a number of concerns including:

- Pupils' views of their experiences of primary science are less positive than those of post-primary pupils.
- Pupils at primary levels are given few opportunities to develop skills of independent enquiry. In particular some pupils specified that at primary level, science had been an infrequent occurrence involving few, if any, hands-on practical activities (p. 142).

The report also suggested that implementation of the Primary Science Curriculum has not yet been fully accomplished. To help address this issue, it recommends that long term, more in-depth continuing professional development should be offered to support primary teachers in the teaching of primary science.

> A key recommendation of this report therefore, is that longer term, more in-depth continuing professional development should be provided to key individuals in primary schools... Access to these professional development experiences could be organised for groups of primary teachers from clusters of schools that would normally feed into the same post-primary school (Varley et al., 2009, p.143).

The 2008/09 annual report of the Primary Professional Development Service (PPDS) (support agency) identified a number of key challenges for teachers which impacted on curriculum implementation in Science. Key challenges that emerged were that:

- Children are not provided with opportunities to engage with the investigative approach to the teaching of science due to teachers' perceived lack of skills and confidence related to this area;
- Teachers still rely heavily on textbooks which do not necessarily reflect the content of the Science Curriculum. A result of this may be that teachers do not teach content relevant to their class level (PPDS, 2009, P.76).

In 2007, O'Keeffe carried out a small-scale study comparing the confidence of five primary teachers in the Republic of Ireland with five of their counterparts in Northern Ireland in the teaching of science. The main finding of the study revealed that the participants from the Republic of Ireland had lower confidence levels teaching science in comparison to their counterparts in Northern Ireland. O'Keeffe states, "this is due to a number of factors including; scientific knowledge, pedagogical knowledge, training and resources/support services" (O'Keeffe, 2007, p. 116). O'Keeffe stresses "Continuing Professional Development will be the key in improving teacher confidence to teach Science" (p. 114).

Corroon (2005), working with teachers from 26 schools, carried out a study to explore Irish teachers' perception of the Primary Science Curriculum (1999). The study sought to identify those factors which might impact on the successful implementation of the science curriculum. The findings of the study suggest that factors such as teacher confidence and availability of appropriate resources impact both on the content and teaching methodologies used. Corroon suggests that her research findings correspond with similar ones found in Scotland (Harlen et al. 1995) and Northern Ireland (Sweeney and Alexander, 2002). For example, all three studies found that teacher confidence and/or competence was the most often cited reason for neglecting a specific content strand unit. Furthermore, all three studies showed that teachers' limitations, with regard to scientific knowledge tended to centre on those topics of the science curriculum focused on the physical sciences (p. 86).

Regarding the provision of continuing professional development, Corroon states, "many of the participating teachers wanted and requested further science in-service to continue their professional development, especially in the area of physical science" (p. 102). She also stresses, teachers' perceptions of the science curriculum days were quite positive although it appears that for a substantial number of the respondents, the days had little impact on their classroom practices (p.93) .Teachers' experiences of the Cuiditheóirí support service appear to have been more beneficial than those of curriculum days, in terms of changing classroom practice.

3.4 International findings - implementation and development of primary science

Primary science has been compulsory in many developed countries such as: New Zealand, Australia and the U.K. for a number of decades. Educators in these countries have provided substantial research on teachers' experiences of teaching science at primary level.

In New Zealand the new primary science curriculum *Science in the New Zealand Curriculum* was implemented in all primary schools in 1995. Within a year the New Zealand Government (Education Review Office 1996) conducted a report to consider the impact of the new science curriculum in primary schools. The report found that a shortfall in teacher expertise and confidence in teaching science was one of the most significant barriers to the successful implementation of the curriculum. Many primary teachers had an incomplete understanding of science, making it difficult for them to cope with the implementation of the curriculum. The report identified the importance of continuing professional development for teachers to address this issue. It also challenged those who manage teacher performance to acknowledge the importance of teaching science, and to give it the priority it required to improve science education (Education Review Office 1996).

Similar results were found in the UK. In a review of the first ten years of compulsory science, Harlen (1998) identified a number of concerns, including: the teacher's own level of knowledge in science, teacher confidence and competence in teaching science, and a teacher's role in constructivist learning. In 2005, Murphy and Beggs (2007) carried out a major study with 300 primary teachers across the UK. The purpose of this research was to establish an overview of the current status of primary science in the UK. The key findings of the study include:

- Many primary teachers feel they lack the confidence to teach science effectively, particularly in relation to carrying out simple science investigations;

- Clear evidence that teacher confidence was increased by their involvement in primary science professional development activities;
- Strong evidence that teachers in smaller schools are less confident to teach science than those in larger schools.

The study emphasises that effective continuing professional development provision in science for primary teachers, is probably the most important factor in bringing about improvements in primary science learning and teaching.

In 1989, science was designated as a “compulsory” subject for all pupils in primary schools in Northern Ireland. In 1996 the Department of Education Northern Ireland (DENI) Inspectorate conducted an examination into the quality of teaching and learning science in a sample of primary schools. They reported that:

- Nearly all children showed an eagerness for science. However, the more able did not realise their full potential due to inadequate opportunities to use acquired skills;
- The teaching of science was successful when teachers used a wide range of teaching approaches which provided suitable balance between instruction and engagement by the children;
- In-service training has had a certain influence on classroom practice. However, a considerable number of teachers were still unsure in their own knowledge of science and needed continued support to further enhance their confidence and competence in the subject.

The report identified a number of areas to be attended to by both teachers and support agencies, including: a clearer understanding of the processes in science, and a need for a substantial number of teachers to increase their confidence in teaching science.

Based on the findings of the literature discussed above, many Irish primary teachers, like their international colleagues lack confidence and competence in teaching science. All the studies and research mentioned above emphasise the significance of continuing professional development for the successful implementation and development of a primary science curriculum.

In Australia, where science has been part of the primary curriculum for more than half a century, the government, science educators, and teachers have voiced concern about the teaching of science in primary schools. Major studies carried out by the Australian Science, Technology and Engineering Council [ASTEC] (1997) , and Goodrum, et al. (2001), revealed concerns including: "a considerable gap between the ideal or intended curriculum and the actual or implemented [science] curriculum" (Goodrum et al., 2001, p. 183), teachers' limited knowledge of science, low teacher confidence, and inadequate resourcing. These studies also revealed that many primary school teachers did not actually teach science, and often, when it was taught, teachers used didactic approaches such as reading from text and rote learning. Goodrum et al. (2001) emphasised that teachers are the key to change, especially to closing the gap between the intended and actual curriculum experienced by pupils.

> the research in this report emphasises repeatedly that the teacher is the most important factor for improving learning. Efforts to close the gap must focus on helping teachers recognise the gap between pupils' real needs in science and what is offered in the actual curriculum. (p. 168).

The report stresses that bringing about change in teachers' professional practice involves significant shifts in attitudes, beliefs and professional knowledge. Among the recommendations arising from this report is the provision of on-going professional development to help teachers develop their confidence and competence to teach science. In an effort to deal with some of these issues a pioneering science programme "Primary Connections" was implemented in 2004. Peers (2006) outlines the aim and desired outcomes of the Primary Connections project:

> … improve the quality and quantity of science teaching and learning in Australian primary schools through enhancing teachers' confidence and competence. This is achieved by developing teachers' pedagogical content knowledge in science and literacy through an innovative programme of professional learning supported with rich curriculum resources (Peers, 2006, p.2)

A large-scale independent examination of the Primary Connections project (Dawson 2009) revealed that the project had been effective in improving teachers' confidence and competence in teaching science. The project also had a positive influence on pupils' attitudes towards science and their understanding of science knowledge. Primary Connections is based on teaching and learning, and professional learning models that are consistent with the international literature on contemporary science education and effective professional development models. Hackling et al. (2007) argue that to improve classroom practice teachers need the backing of quality professional learning and curriculum resources. Furthermore, they stress the provision of professional learning workshops, successful pedagogical experiences, opportunities for collegial interaction and reflection on practice, are required for successful implementations of new initiatives (p. 4).

3.5 Summary

For most of the last century, science as a subject, did not secure a strong foothold as part of the curriculum in Irish primary schools. Prior to the introduction of the revised Primary Science Curriculum in 1999, pupils for the most part, did not encounter science (especially physical science) until they entered secondary school. Provision of science at primary level was somewhat haphazard, ranging from little more than nature study in many primary schools, to some inspired science teaching in others. Matthews (1993) maintains that the neglect of science education in our primary schools during the last century may reflect the poor image of science (and applied science) that has been prevalent in society as a whole (p. 39). He argues that this neglect is unfortunate in at least two respects: (a) Irish children have been shown to perform less well than children from other countries in science related activities; (b) it is a truism that science is the dominant cultural activity of the twentieth century, and as such, the school curriculum should acknowledge the importance of science and provide opportunities for children to develop an understanding of its subject matter, powers and limitations (p. 39).

The implementation of the 1999 science curriculum means that science is now an established and central part of the curriculum in every primary school, and this is very welcome. The introduction of the new Primary Science Curriculum has important consequences for the position of science in Ireland, for public awareness of, and access to science, and for the education of future scientists and scientifically literate citizens: "greater confidence with science and technology is an important condition for technological innovation in the community. The availability of more people with science training is a prerequisite for the development of an economy capable of maintaining its citizens into the 21st century" (ICSTI, 1998, p. 1). Compared to other developed countries, Ireland has been comparatively late in acknowledging the need for science education to be compulsory in the primary school curriculum. This gives it the advantage of being able to learn both positive and negative lessons from the experience of others (p. 10).

A key concern identified in this chapter was the need for on-going support for teachers in the form of professional development, to ensure the successful implementation of the science curriculum. With the revised primary science curriculum now into its 9^{th} year there is still a shortage of recent and relevant research regarding the implementation of the primary science curriculum in primary schools in Ireland. Science educators and teachers need to take stock and ask a number of important questions regarding primary science. Do our teachers lack confidence? Do many teachers have negative attitudes towards teaching science? If the answer to these questions is yes, then, what should be done to counteract this? It is important to learn from concerns voiced, and mistakes made in other countries. What should we do differently to prevent the same problems for primary science in Irish schools? It is clear that substantial and sustained investigation of the teaching and learning of primary science, especially teacher attitudes to and confidence in teaching science, should be of considerable importance to all involved in primary science in Ireland. Teachers need on-going support in the form of professional development to successfully implement the primary science curriculum. However, the type of professional development teachers receive is critical. This will be discussed in detail in Chapters Four and Five.

Chapter 4
Attitudes and Capabilities in Science Education: A Review of Literature (Part 1)

Introduction

The literature review presented in this chapter and Chapter Five will seek to shed light on the background to the research questions discussed in Chapter One, and thus enrich the context for the conduct of the enquiry. For the purposes of clarity the literature review is divided into two chapters. This chapter is concerned with the research literature relating to pupils' and teachers' attitudes to science, and Chapter Five reviews the related literature on teacher professional development that informs this study. Important works by some major contributors to research in both of these areas are reviewed. The ideas and insights thus yielded, serve in turn to enlighten the methodology for this study, which follows in Chapter Six.

This chapter is divided into six parts. The first part (section 4.1) considers definitions of attitude and attitudes towards science. In part two (section 4.2) studies of factors affecting pupils' attitudes in relation to science in education are investigated and examined. The third part (section, 4.3) explores teachers' attitudes to science and science teaching and the effects of this on the experienced quality of learning among the pupils, including their attitudes towards the subject. Part four (section 4.4) probes the various approaches used to gather information on attitudes to science. Part five (section 4.5) discusses a number of factors affecting teachers' levels of confidence in science. This section is divided into two subsections, the first (section 4.5.1) examines teacher proficiency in science, and the second (section 4.5.2) explores the importance of teacher *pedagogical* content knowledge in science in the effective teaching of science. The final part (section 4.6) identifies the implications of teacher confidence, competence and attitudes to science for the provision of professional development programmes in primary science.

4.1 Attitudes towards science

A common problem for researchers studying attitudes to science is a definition of *attitude* itself (e.g., Gardner, 1975; Ramsden, 1998; Osborne et al., 2003). Attitudes are, in general, defined as a predisposition to react either positively or negatively to people, places, or things. They include: feelings, motivation, interest, enjoyment and selfesteem. Siegel and Ranney (2003) state, “in the educational and psychological research literature, many ways of categorising attitudes have been developed, from disposition to opinion, and from affect to belief” (p. 757). A general definition has included describing attitudes as including the three components of *cognition*, *affect*, and *behaviour (*Ajezen and Fishbein, 1980). According to Oppenheim (1992):

> ...attitudes are normally a state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli... attitudes are reinforced by beliefs (the cognitive component), often attract strong feelings (emotional component) which lead to particular behavioural intents (the action-tendency component) p. 175

Reid (2006, p. 4) defines these three components as:

- A knowledge about the object, the beliefs, ideas component (Cognitive);
- A feeling about the object, like or dislike component (Affective);
- A tendency-towards-action, the objective component (Behavioural).

Gardner (1975) and Schibecci (1984) examined the literature on attitudes in science education; they distinguished two broad categories of science-related attitudes, namely attitudes towards science and scientific attitudes. Gardner defines attitudes towards science as “a learned disposition to evaluate in certain ways objects, people, actions, situations, or propositions involved in the learning of science” (Gardner, 1975, p. 2). They include interest in, and enjoyment of science, as well as the usefulness of science. On the other hand, scientific attitudes are more concerned with scientific ways of thinking and, as Koballa (1995 p. 62) suggests, “embody the characteristics of attributes of scientists that are considered desirable for pupils, such as open mindedness, a questioning approach, a search for data and their meaning, and a demand for verification”. Most of the educational research on attitudes relates to attitudes towards science. This study is specifically concerned with attitudes towards science, and in particular the pupil’s/teacher’s liking or disliking science.

4.2 Factors affecting pupils’ attitudes to science education

There is concern among political and educational circles in Ireland and many other countries, such as the UK, Australia and the USA, (Goodrum et al. 2001; Child, 2002; Osborne et al. 2003) regarding the lack of pupils’ interest in science, and the decline in the number of pupils opting to study science in post-compulsory education. This decline in the uptake of science, especially physical sciences, has prompted a renewed interest in attitude research (Osborne, et al., 2003). Kobella (1988) suggests this interest has arisen because affective factors are seen to be just as significant as cognitive factors in affecting the quality of learning. Many specific findings on attitudes can be found in the literature, including: pupils' attitudes toward science compared to other school subjects; the association between attitudes to science and factors external to school e.g. age, gender, and the influence of teacher behaviour on pupils' attitudes. Kobella (1988) suggests that pupils' attitudes towards science affect their learning outcomes, their selection of science subjects at secondary school, and their career choice.

There is much evidence that points to affective factors as being particularly influential in determining subject choices. Simpson and Oliver (1990) stress that a positive attitude toward science "leads to a positive commitment to science that influences pupils' lifelong interest and learning in science" (p. 14). There is concern over the low level of uptake of science by pupils in post compulsory education (Murphy & Beggs, 2002). A number of researchers have indicated that part of the reason for this is that pupils are "turned off" science at school at a very young age (p. 13). Murphy and Beggs (2003) working with primary pupils across the UK, found that younger pupils (8 – 9 yrs) have considerably more positive attitudes to science than older pupils (10 – 11 yrs). Pell and Jarvis (2001), carrying out research with 800 primary pupils in English primary schools, found that pupils' interest in science fell as they moved up through the educational system. Osborne et al. (1998) suggest that children form attitudes to science at a young age, and these tend to peak at age 11.

A number of factors have been put forward to explain pupils' declining interest in school science. Osborne et al. (1998) identified five factors which were important in forming attitudes to school science: gender, ethnic background, home life of pupil, perceived difficulty of subject and the effectiveness of the teacher. Haladyna et al. (1982) identified three important factors affecting pupils' attitudes to science: the pupil, the teacher and the learning environment. They argued that the most important factor is the type of science teaching they experience. Simpson and Talton (1986) found that the teacher and the classroom climate were the variables that had the strongest relationship to pupils' perceptions of science.

Studies by Myers and Fouts (1992) and Woolnough (1994) have also shown the influence of the classroom environment on pupils' attitude towards school science.

Myers and Fouts (1992), working with secondary school pupils in the USA, found that the pupils with the most positive attitudes to science were those who actively engaged in science, received a high level of personal support from teachers, and were in classes where teachers used a variety of teaching methodologies. Woolnough (1994) established that the most significant factor affecting pupils' attitude was the nature of teaching they experienced. Furthermore, Woolnough found that secondary pupils' awareness that their teacher enjoys science and has strong skills in teaching may have an influence in their later decisions about future course selection. The Acclaim project in the UK (www.acclaimscientists.org.uk) interviewed a number of renowned scientists. One of the most interesting findings from the interviews was the age at which the scientists decided that they had first become interested in science. Typical responses included: "I was interested in science from a very early age, perhaps five or six", and "I don't remember when I was not interested in science". Significantly, the scientists stressed that both teachers and hands-on science experiences, played an influential role in developing their interest in science.

4.3 Teacher attitudes to science and science teaching

Rennie, et al. (1985), carrying out a study with primary school teachers in Australia, found that teachers' attitudes and behaviours regarding science and technology were a significant influence on the attitudes of their pupils. Most significantly, they found that both teachers' and pupils' attitudes became more positive over the period of the study, suggesting that attitude change had incrementally taken place. Research by Simpson and Oliver (1990) and Haladayana et al. (1982) also indicated teachers' attitudes and behaviours in relation to science as critical influences on the attitudes of their pupils. They identified two aspects of a teacher's behaviour as being important: (a) teachers' own attitudes towards science and science teaching, and; (b) their pedagogical approach. Tobin et al. (1994) suggest that teachers' attitudes toward science teaching are a critical component determining the quality of their classroom practice. Simpson and Oliver (1990) suggest that teachers' own attitudes to science may be "transmitted" in some way to children. This may not be a deliberate effort to change attitudes but the unconscious effects of one person's attitudes and ideas upon another. They argue that, if primary teachers are not as motivated in teaching science as they are other subjects, it is more than likely that the pupils will not receive sufficient experience of science, including its attractions and possibilities (p. 16). This can develop into a descending spiral of negative attitudes towards science, resulting in the majority of pupils only taking the minimum amount of science in the course of their formal education after primary school. Many primary science teachers can have negative attitudes towards teaching science, stemming from factors such as: the fact that they did not learn it in school; negative experiences of science in their own education; lack of confidence and/or competence in teaching it.

The effect of teachers on pupils' attitudes to school subjects, especially science, has also been researched in Irish schools. In 2003, the National Council for Curriculum and Assessment (NCCA) carried out a review of the Primary School Curriculum in the Republic of Ireland (NCCA, 2005). Findings in its report were based on data from over 700 completed teacher surveys and interviews with children, parents, teachers and principals in six schools. Part of the review involved questioning pupils about their attitudes to different subjects presently on the curriculum. Children reported that "the attitude of their teacher toward teaching and learning in specific subjects also contributed to their likes and dislikes." (p. 196). A study of Irish secondary schools by Smyth and Hannan (2002), involving over 4,000 pupils along with detailed case-studies of science teaching within eight schools, identified a number of factors which affect the take-up of science subjects at senior cycle. The study established that a higher number of pupils opted for science subjects at senior cycle in schools where teachers emphasised practical work and pupil participation at both junior and senior cycle. A small-scale research study by Smith (1999) found that pupils who were taught science using a Science, Technology and Society (STS) approach, developed significantly more positive attitudes towards science teachers, than did pupils who were taught using "traditional approaches". Using an STS approach, teachers act as facilitators of knowledge, dispense less information while encouraging pupils to ask more questions, and relate science content to the day-to-day lives of the pupils. Smith cites the increase in positive attitudes towards science teachers as a significant contributor to the increase in pupil numbers opting for science subjects at senior level (p.117).

In summary, the research literature regularly confirms that teachers are a key influence on pupils' developing positive or negative attitudes towards science, especially in primary school when children have their first formal science experiences.

4.4 Gathering information on attitudes to science

Osborne et al. (2003, p. 1055) reviewed the literature on the different approaches used to measure attitude. They list the following five approaches:

- Preference ranking – attitudes towards school subjects can be found very easily by asking pupils to rank their liking of school subjects.
- Attitude scales – most common approach for measuring attitudes and appears in a number of forms including Likert scales, Thurstone-type scales and semantic differential scales. Likert scales ask the pupils to reply to a number of statements by selecting from a five-point score such as *strongly agree, agree, neutral, disagree, strongly disagree*. Thurstone-type scales ask pupils to choose a statement from a list that best reflects their attitudes. Semantic differential scales ask pupils to rate a particular object (e.g. good/bad).
- Interest inventories – present pupils with a list of items and ask them which one they are most interested in.
- Subject enrolment – involves the collection of data on enrolment in various subjects.
- Qualitative methods – explore pupil attitudes using interviews.

The majority of studies carried out by researchers into attitudes to school science have shown a reliance on gathering evidence using attitude scales, usually in the form of a fixed response questionnaire. An attitude scale such as the Likert scale has a number of advantages including that it is easy to create, easy to process using statistical analysis, and can provide high reliability. The Likert scale has been widely used in science education. Examples include the Test of Science Related Attitudes (TORSA) devised by Fraser (1981). TORSA is designed to probe the attitudes of secondary school pupils' attitudes to science. In 2001 Pell and Jarvis developed an instrument "Pupils' Attitudes to Science" for use with primary pupils aged 5 – 10 years. However, a criticism of attitude scales is that their usefulness is limited to identifying the nature of the problem; they provide little opportunity to understanding it (Ramsden 1998).

The past two decades have seen a growth in the employment of qualitative instruments used to probe attitudes to science. An example of a study that draws on open responses of respondents is the Views on Science-Technology-Society (VOSTS) study carried out in Canadian schools by Aikenhead and Ryan (1992). This study involved the questioning of teenagers with statements related to science, and asking them their opinions on the various statements. Other studies (Pilburn & Baker 1993 and Osborne & Collins 2000) have relied only on interviews with respondents as a way to explain their findings. Osborne et al. (2003) maintain that qualitative methodologies have value in researching attitudes towards science:

> Whilst such studies [qualitative studies] are subject to restrictions of their generalizability, the richness of data does seem to give more insight into the origins of attitudes to school science than quantitative methods (p. 1059).

Selwyn et al. (2009, p. 912) argue for the use of children's drawings as a valuable method of assessing children's attitudes and needs at primary level. Furthermore, they stress that over the last 20 years drawing-based methods of data collection have been used to examine educational areas such as teacher-child relationships and the classroom environment. This will be discussed in more detail in Chapter Six (section 6.5.1).

Since the present study seeks to both verify and understand attitudes towards science education, the researcher employed both quantitative and qualitative instruments to probe teachers' and pupils' attitudes to school science (these will be discussed in more detail in Chapter Six). This offers the researcher a number of benefits, which include:

- generating multiple data sources, with more checks on trustworthiness and validity of the results;
- enriching the quality of the findings – revealing a greater awareness of what, how and why something is happening;
- allowing exploration of the processes of the study as well as the outcomes.

4.5 Teacher confidence and understanding of science

The last two decades have seen a big increase in research on primary teachers' confidence in teaching science. Studies by Kruger and Summers (1989) , Summers and Kruger (1992), and Jarvis and Pell (2004) demonstrated that many primary teachers not only lacked confidence and perceived competence to teach science, but they also possessed an incomplete understanding of science concepts. Research by Wragg, Bennett, and Carre at Exeter University emphasised the point that background knowledge of science in primary teaching is more complex than merely having an adequate knowledge of certain concepts (Wragg et al., 1989). Wragg and colleagues surveyed over 900 teachers across 51 primary schools, to establish the teachers' perceptions of their competence and needs with regard to the new National Curriculum in the UK. Findings revealed that teachers perceived themselves as most competent in English, with mathematics in second place. Thirty four per cent (34%) of the teachers felt confident in their existing knowledge and skills, in science. This placed science eighth out of the ten primary subjects that the teachers felt competent to teach. A large number of the teachers stated that they needed a good deal of support in the form of professional development, especially in the physical sciences.

This research was followed up two years later in 1991, when the National Curriculum in the UK was in its second year. Of the 433 teachers surveyed for the project, forty one per cent (41%) now felt competent with their existing science knowledge and skills. Thus science moved from eighth place to third place. The researchers attributed this change in the teachers' perceptions of their own competence in science, to their experience of teaching National Curriculum science over a two year period (Carre & Carter 1993). Carre and Carter stressed that it seemed conceivable that a number of factors, including gains in science subject knowledge, pedagogical content, and curriculum goals accounted for this increase in teacher confidence. They reported that teachers' perceptions of their competencies in primary science had an effect on their capability to teach primary science. Furthermore, they maintained that teacher confidence and competence in implementing the new science curriculum in primary schools was the significant factor influencing successful implementation.

4.5.1 Teacher proficiency in science

Teachers should have a good grasp of their subject matter in order to teach that subject well. However, research tells us that primary school teachers all too often have limited science knowledge, and that this results in low confidence teaching science (Osborne & Simon 1996; Goodrum et al., 2001).

There is a considerable amount of research that shows primary teachers' understanding of key science concepts is often different from the usually accepted scientific standpoint i.e. they may not reflect the ideas that scientists themselves hold (Kruger & Summers, 1989; Harlen & Holroyd, 1997; Jarvis, Pell & McKeon 2003). Many of the teachers' ideas are comparable to the "misconceptions" or "alternative conceptions" generally held by children (Driver, 1983). If teachers have a restricted science knowledge they are not likely to be conscious of children's misconceptions and therefore, are unlikely to present their pupils with scientifically accepted explanations. They are likely to give misleading information in an effort to explain science to their pupils, and their own deficient conceptions of science might get in the way of their pupils' understanding (Osborne and Simon, 1996).

McDiarmid, Ball and Anderson (1989) suggest that "teachers' capacity to pose questions, select a task, and evaluate their pupils' understanding, all depend on how they themselves understand the subject matter" (p. 198). Osborne and Simon (1996) argue that primary school teachers' lack of confidence and ability can end up with them using less stimulating teaching methods, and not responding effectively to pupils questions in science class. Osborne and Simon strike a pessimistic note when they state:

> ... the implementation of the prescriptive demands of a national Curriculum for primary science by teachers lacking essential subject knowledge presents the risk of decreasing interest and motivation in science for young children. In short, the difficulties caused by teacher subject knowledge may be the rock on which primary science education may founder. (p. 135)

In 1993, Harlen, Holroyd and Byrne (1995) conducted a major research study with teachers in 119 primary schools in Scotland. One of the main aims of the research was to investigate "how teachers perceive their competence in helping children to achieve the attainment outcomes in science and technology" (p. 9). The study confirmed anxieties about the confidence of primary teachers in teaching science. In the sample of 514 teachers, 63% of teachers had no qualification in science. 41% of teachers gave science the lowest confidence rating. This compared with 1% for English and mathematics. 71% of teachers felt completely confident to teach English and mathematics. However, only 12% had the same confidence about teaching science. In a follow-up research survey in 1996 with fifty-seven primary teachers in Scotland, Harlen and Holroyd (1997) found there was a positive association between levels of confidence in teaching science, and the teachers' own scientific understanding. Their report showed that inadequate science knowledge was a major factor that influenced primary teachers' confidence in teaching science. The researchers investigated the degree to which problems encountered in primary science were linked with the lack of confidence and/or background knowledge. According to the researchers, primary teachers with low confidence used a range of "coping strategies" to teach science (1997, p. 103). These strategies included:

(a) only teaching the minimum amount of science required;
(b) emphasising areas they feel most confident in, such as biology;
(c) placing reliance on prescriptive texts and work cards;
(d) playing down questioning and discussion;
(e) only doing very undemanding practical work.

Harlen and Holroyd concluded that such strategies "can have a severely limiting effect on pupils' learning" (1997, p. 103). When these coping strategies become the norm, pupils' achievement will be incomplete (Osborne & Simon 1996). Appleton and Kindt (1999) reported that the normal response for teachers with low self-confidence in science is to steer clear of teaching the subject or use various "avoidance stratagems".

A report by the British Council for Science and Technology (2000) regarding the quality of science teaching in primary and secondary schools in the UK, showed that in spite of a decade of compulsory primary science, primary teachers were in general less confident about teaching science than they were about mathematics or English. It confirmed that the efficiency of teachers springs mostly from their attitude, their confidence, their knowledge of science, and of how to teach it. In 2005 Murphy et al. (2007) carried out a large-scale UK-wide survey to ascertain primary teachers' confidence in teaching science and to investigate the influence of science initiatives taking place in UK primary schools. The research involved a telephone questionnaire of over 300 primary teachers. The authors compared their results with the results of a report (mentioned above) carried out a decade earlier by Harlen et al. (1995) in Scotland. The findings indicated that there were improvements in a number of areas of primary teachers' confidence in teaching science. However, over half of the teachers questioned referred to a lack of knowledge, confidence and ability to teach science as being their most important worry in teaching primary science.

In Ireland, the inclusion of science as a subject in the 1999 primary school curriculum has put Irish teachers' science knowledge and understanding under the spotlight. Walsh (1999) argues that one of the most serious challenges to the successful introduction of the new primary science curriculum is the problem of scientifically illiterate teachers. He claims, "that for science in-service [education] to be effective, considerable effort will need to be directed towards providing teachers with the necessary expertise to fill the void that exists in schools" (Walsh, 1999, p. 7). A small-scale study by O' Keeffe (2007), investigating confidence levels of primary teachers in teaching science emphasised the importance of science knowledge to teacher confidence. O'Keeffe states, "the teachers with the most scientific background knowledge also had the highest levels of confidence in teaching the subject' (p.108). Research by Corroon (2005) found that teachers in her study were likely to teach science topics in the biological science area more frequently than those from the physical science area. Corroon cites teachers' lack of confidence and competence in these topics as the main reason for this. A recent survey conducted with a cohort of second year pre-service teachers (400) in an Irish primary teacher education college revealed a number of concerns regarding pre-service teachers' competence and confidence in teaching science (Murphy & Smith, 2012). Data collected from questionnaires indicated that 97% of these pre-service teachers studied Junior Certificate Science; 68% studied Biology at Leaving Certificate level, 8% studied Physics and 17% studied Chemistry at Leaving Certificate level. The majority of these pupils revealed inadequate scientific understanding of a number of scientific concepts relating to physics, chemistry and biology. The survey also indicated that a high percentage of these second year pre-service teachers appeared to be anxious about their own low levels of subject knowledge in science, and did not feel confident about teaching science in primary school as a result.

4.5.2 Teacher pedagogical content knowledge

The research literature shows that even when teachers have a firm grasp of subject knowledge, effective teaching is not automatically guaranteed (Russell et al., 1992; Golby et al., 1995). Both of these studies argue that subject knowledge is only part of a complex set of factors a teacher needs to teach effectively. Other factors include:

- Teachers' attitude to the subject;
- Teachers' ability to select appropriate and enjoyable experiences for the pupils;
- Teachers' ability to connect one area of subject learning with others;
- Teachers' ability to interact with pupils in the lesson, including identifying misconceptions and giving appropriate explanations.

In this context, pedagogical content knowledge has been identified as a crucial element. In a seminal piece of work, Shulman (1986, 1987) suggested that teachers' professional knowledge embraces a variety of categories. These are:

1. Content knowledge - about science and of science;
2. General pedagogical knowledge - about classroom management that goes beyond subject matter;
3. Curriculum knowledge - guidelines, national requirements and materials available;
4. Pedagogical content knowledge - about how to teach the subject matter, including useful illustrations, powerful analogies and examples;
5. Knowledge of learners and their characteristics;
6. Knowledge of educational contexts;
7. Knowledge of educational goals, values and purposes.

A key concept here is Pedagogical Content Knowledge (PCK). Shulman portrayed pedagogical content knowledge as an amalgam of subject knowledge and general pedagogical knowledge:

> A special amalgam of content and pedagogy that is uniquely the providence of teachers ... Pedagogical content knowledge … identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to diverse interests and abilities of learners, and presented for instruction. (Shulman,1987, p. 8).

He conceptualized PCK as including "the most powerful analogies, illustrations, examples, explanations, and demonstrations i.e. the ways of representing and formulating the subject that makes it comprehensible for others" (1986, p. 9). Magnusson et al. (1999), maintain that PCK for science teaching includes: what teachers know about learners, curriculum, instruction, and assessment that helps them to change content knowledge into effective teaching, i.e. teaching which supports learning and understanding. Thus, the interaction of a teacher's knowledge and understanding with that of his pupils is a crucial factor in the classroom. PCK incorporates both content knowledge and pedagogical knowledge, and it is an essential concept for effective science teaching. Watt's and Simon (1999) argue that subject knowledge and pedagogical content knowledge have complementary roles in teaching.

> Subject knowledge alone does not guarantee an ability to package the ideas in a form which will be accessible to others; similarly, pedagogical content knowledge without any understanding of the underlying science could lead to problems in sequencing sessions and in ensuring that the science is clearly linked to the objectives of the activities (p 387)

A study by Hashweh (1987) used the concept of pedagogical content knowledge to explore teachers' knowledge of science and their planning and teaching of a lesson. Hashweh carried out an extensive study of six secondary school teachers' knowledge of science (three physics and three biology) and the influence of this knowledge on their teaching. Hashweh found, teachers who were teaching topics within their own subject expertise had more knowledge of linked concepts, and ways of linking one concept with another rather than those teaching topics outside their own subject expertise. Hashweh gives the example of the topic photosynthesis. The biology teachers were aware of the specific misconceptions that their pupils were likely to hold regarding this topic (e.g. a common misconception their pupils held was that plants get their food from the soil and not the air). The biology teachers also knew the concepts that were most difficult for their pupils (e.g. conversion of ATP to ADP and ADP to ATP) and the most appropriate way to deal with those difficult concepts. However, the physics teachers had few specific ideas for teaching difficult biology concepts. Also, when teachers in the study were asked about their knowledge in the discipline that was not their subject of expertise, they displayed more misconceptions.

According to Van Driel, et al. (2002) professional development programmes in science teachers' pedagogical content knowledge should contain the following features: on-going co-operation between science teachers, and between science teachers and science educators, focusing and reflecting on authentic teaching practice, and possibly including experiments and research activities designed and conducted by science teachers themselves.

In the Irish context, Palmer (2001) highlights the importance of primary teachers having a good range of science teaching methodologies to employ in class as well as having good classroom organisation and management skills. She maintains, if the primary science curriculum is to be fully implemented in the Republic of Ireland, the developmental needs of teachers will be a major challenge. Palmer emphasises that primary teachers require not only scientific understanding but also appropriate pedagogical skills and self-confidence in the teaching and learning of science.

4.6 Summary of salient issues

Internationally there has been concern over the declining number of pupils deciding to prolong their science education beyond the minimum school leaving age. Research (Jarvis & Pell 2001; Murphy & Beggs, 2003) shows that this could be due to the attitude to science they have developed from their school experience, especially during their primary years. Evidence identified in this chapter clearly demonstrates that primary teachers' attitudes towards science teaching, their pedagogical content knowledge and their science content knowledge can have a crucial impact on the attitudes of their pupils to science. Research findings have revealed problems connected to poor teaching of science at primary school. These include many primary teachers: having negative attitudes towards science, lacking confidence in teaching science, and often lacking scientific knowledge and indeed holding misconceptions regarding scientific concepts. The research studies also show that teachers with low self-confidence and/or poor science content knowledge tend to avoid teaching science altogether or use teaching strategies which avoid engaging pupils in science. If primary teachers are to teach primary science effectively it is important for them to convey a positive attitude to science as well as being knowledgeable about science and its associated pedagogy.

These findings have consequences for future teacher professional development programmes in primary science. Any future professional development programme must be concerned with enhancing teachers' science knowledge. However, it is not sufficient for any programme to focus only on enhancing teachers' science knowledge. Professional development programmes also need to provide teachers with an in-depth knowledge of how to present science matter to learners, and to provide teachers with opportunities to scrutinize their own learning. Similarly, it is important that professional development programmes engage with teachers' attitudes to teaching science in school, with a view to changing them if they are negative.

It is important to investigate how primary teachers' attitudes to teaching science, their science competence, and their confidence in teaching science affect their pupils' attitudes to science and whether professional development programmes can influence these attitudes. The formulation of the particular model to be used in the present study will be informed by these concepts. The research in this study will attempt to provide a relevant contribution to this area. It will investigate primary teachers' attitudes towards science and science teaching with a view to exploring how they relate to their pupils' attitudes. The underlying assumption of this study is that attitudes will affect behaviour and that developing positive attitudes amongst teachers, in addition to developing their pedagogical capacities in science, will lead to more effective science teaching and improvement of their pupils' attitudes towards science.

The next chapter reviews the related literature on teacher professional development and presents evidence intended to support the rationale for carrying out this study.

Chapter 5
Some Key Issues in Continuing Professional Development: Review of the Literature (Part 2)

Introduction

Prior to developing a model of professional development, research on what makes professional development effective should be undertaken – ensuring the model or programme is focused in the right areas. Programmes of professional development should be informed by research and literature.

The review first distinguishes between in-service courses and professional development and discusses several definitions of professional development (section 5.1). The second part (section 5.2) reviews the current state of international professional development for teachers, particularly research findings on its adequacy, and on its impact in the classroom. It also examines the literature on the characteristics of effective professional development. Part three (section 5.3) explores a variety of models of professional development that offers a range of approaches for teachers and considers aspects of each that could be incorporated into this study. This is followed by part four (section 5.4), investigating the complexity of changing teachers' classroom practice and how professional development can bring about this transformation. The fifth part (section 5.5) examines the importance of evaluating professional development programmes and proposes a framework of evaluation to be used in the present study, based on Guskey's model of evaluation (2000). The sixth part (section 5.6) explores the influence of professional development in breaking down teacher isolation, especially in small rural primary schools, and establishing professional learning communities. The final part of the chapter (section 5.7) identifies a number of the salient issues regarding research findings that have implications for designing effective professional development programmes.

5.1 Professional development

Chapter Four identified the target area for this study – the challenges to the effective teaching of primary science in Irish schools: teacher confidence, competence, attitudes to teaching science, subject knowledge and the need for support. With that context in mind, this chapter will consider the design for professional development programmes with a view to developing an effective design for the model of continuing professional development that will be used in this study.

The processes of teaching and learning are constantly changing, e.g. changing pupil needs, changing knowledge bases and teaching methodologies (Hawley & Valli, 1999). If teachers are to keep abreast of these changes they need to participate in continuing professional development. Guskey and Huberman (1995) state “Never before in education has there been greater recognition of the need for on-going [teacher] professional development... Regardless of how schools are formed or reformed, structured or restructured, the renewal of staff members' professional skills is fundamental to improvement” (p. vii).

In any discussion about professional development it is important to be clear of what the term actually means. Often, the terms "inservice courses” and "professional development” are used interchangeably. Distinguishing between the two will be helpful for this study. In-service courses in Ireland have traditionally been presented as short-term, distinct, seminars and workshops. It tends to follow a somewhat standardised format – teachers attending an assigned workshop given by an outside “expert” at which they learn new skills and information which they are then expected to use in their day to day teaching practice. Sugrue (2002) stresses “in-service carries overtones of ‘quick fix’ periodic episodes of ‘input’ which teachers are expected to bring back to schools” (p. 313). A key concern with in-service is that it is perceived as a top down transfer model where information is dispatched to teachers for them to apply in their classrooms (Rose & Reynolds, 2006, p. 220). However, in-service education does offer a number of benefits – providing teachers with certain types of information such as new specific teaching skills (Little, 1993), new ideas and teaching tools (e.g. computer software) in a convenient and economical way.

By contrast, professional development is the long-term systematic support for teachers to change their practices, it is provided throughout the course of their teaching career. “It [professional development] is used more inclusively to embody personal, professional and social dimensions of an individual’s growth and development, thus shedding narrower, vocational connotations embodied in the term in-service” (Sugrue et al. 2001, p. 9). Guskey (2000) describes professional development as “those intentional, on-going and systemic processes and activities designed to enhance the professional knowledge, skills and attitudes of educators so that they might in turn, improve the learning of pupils" (p. 16). Fullan (1991) defines professional development as a lifelong process, beginning with the initial preparation of teachers and continuing throughout their teaching career. Furthermore, he argues that continuing professional growth is the sum total of formal and informal learning experiences throughout a teacher's career (p. 326). Day (1999) captures some distinctive features of teacher professional development, including personal, professional and social development:

> Professional development consists of all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school and which contribute through these to the quality of education in the classroom. It is the process by which, alone and with others, teachers review, renew and extend their commitment as change agents to the moral purposes of teaching; and by which they acquire and develop critically the knowledge, skills and emotional intelligence essential to good professional thinking, planning and practice with children, young people and colleagues through each phase of their teaching lives. (p. 4)

Day's definition points to many formal and informal activities which teachers participate in individually or in groups for personal and professional growth. Unfortunately, many teachers' perceptions of what activities make up professional development is often restricted to attendance at workshops and short modular courses, and seen as a separate "add on" to the job (Hogan et al., 2007).

5.2 Towards more effective forms of professional development

Three broad categories of need can be identified within continuous professional development for teachers: those concerned with the needs of the system, the needs of the school and the needs of the individual teacher (Hogan et.al 2007). Effective professional development provides appropriately for all three. This study is concerned principally with the needs of the teacher, thus, the literature on effective professional development pertinent to this area is considered.

A review of the professional development literature shows considerable criticism of traditional forms for failing to have lasting effects on classroom practice. The traditional approach to professional development tends to be a one-step approach to teacher learning: "that promotes a conception of teaching as a 'craft' with a mastery resulting from the progressive accumulation of knowledge and skills." (Hoban, 2002, p, 21). Many types of professional development courses have been designed on the basis that educational change is mainly about presenting teachers with new ideas to implement in their classrooms. Such an approach sees innovation as something new arriving on the scene, the teacher using the new arrival and the teacher changing as a result of this. The strength of this approach is that it presents teachers with deeper understanding of what they already know, and presents knowledge that is worth replicating. It is also an expedient and cost-effective way to present new knowledge to teachers. However, such an approach does not consider: the context of the school, resistance and attitudes of teachers to change, and that teacher change is more a process than an event.

Hawley and Valli (1999) reviewed the literature on professional development for teachers and concluded, "Conventional approaches to professional development, such as one-time workshops, typically do not lead to significant change in teaching methodologies" (p. 129). King and Newmann (2000, pp. 576-577) observed that conventional professional development does not meet several key conditions for teacher learning, because:

- Most professional development activities involve brief workshops or conferences with no provision for follow-up or feedback;
- Materials and sessions are usually presented by experts, but these resources are not integrated into existing systems of peer collaboration;
- Most professional development activities are dictated by administrators with little teacher input.

From an Irish context, a report commissioned by the Teaching Council of Ireland (2009) to inform discussions and policy formation on teacher education in Ireland, found that despite the advances in professional development provision over the last decade, professional development in Ireland is still often short-term, once-off, and not as clearly linked to teachers' professional practice as it might be (p. 201). Hawley and Valli (2000) sum it up best when they state, "If we spend more time and money on traditional forms of professional development, such as workshops, conferences, presentations, and courses remotely related to the daily challenges of teaching, we can expect little return on our investments" (p. 1).

Over the last decade or so professional development has been undergoing profound change, primarily from the “one size fits all” isolated in-service workshop, to more on-going programmes situated in teachers’ real work – focusing on classroom practice and pupil learning (Kennedy 1998; Supovitz & Turner 2000;Hogan et. al 2007). There is a consensus among many researchers that effective professional development should challenge teachers’ intellect, add to their skills and knowledge, and most importantly, lead to improvements in their classroom practice.

There is an extensive body of literature illustrating the various characteristics of effective professional development. A number of educational researchers (Garet et al. 2001; Guskey 2003; Loucks-Horsley et al. 2003) have summarised much of this literature, particularly the key charactistics of effective professional development needed to improve teaching. Garet et al. (2001), in a large scale analysis of teacher professional development (1000 mathematics and science teachers), compared the influences of different characteristics of professional development on teachers’ learning. They reported that:

- Duration and contact hours of professional development influence teachers' active learning in professional development experiences;
- Active learning enhances teachers' knowledge and skills;
- Activities that emphasizes content relevant to curriculum enhances teachers' knowledge and skills;
- Enhanced knowledge and skills are likely to lead to change in teacher practice;
- Coherence of the professional development programme (i.e., alignment with the teachers' classroom/school culture) influence teachers to change their classroom practice;
- Collaborative professional development (e.g. the same school, grade, subject) influence the scale to which teachers changed their classroom practice.

(Garet et al., 2001, pp. 930 -934)

After reviewing numerous lists of characteristics of effective professional development Guskey (2003) identified 21 characteristics. The five characteristics he most frequently mentions are: (1) improving teachers’ content and pedagogical knowledge, (2) providing sufficient time, (3) supporting collegial and collaborative exchange, (4) a system for evaluating the professional development (PD) experience, and (5) carrying out school or site-based professional development. Loucks-Horsley et al. (2003) present seven characteristics of effective professional development. Although four of these overlap with those of Guskey, Loucks-Horsley and colleagues outline three extra ones: (a) creating a well-designed image of effective classroom learning and teaching, (b) supporting teachers to serve in leadership roles, and (c) establishing a professional development design centred on research and involves teachers as adult learners.

A conclusion that can be taken from these research studies is that the characteristics that influence the success of professional development are numerous, complex and there is no "one size fits all" model for effective professional development programmes. Therefore, the characteristics of effective professional development must be carefully thought through as one plans and implements professional development programmes. The characteristics most commonly supported by educationalists as enhancing the quality and success of professional development include that it should:

- Enhance teachers' content knowledge and pedagogical knowledge;
- Be on-going and sustained;
- Involve active engagement on the part of the participants;
- Be job-embedded;
- Be collaborative and collegial in nature;
- Encourage teachers to reflect on their learning.

These six characteristics are very significant to the present study because they incorporate the personal, social and professional development of teachers, as described by Day's definition of professional development (1999) outlined earlier. As well as enhancing teachers' knowledge and skills, these characteristics also give the researcher an insight and understanding of the participants and processes that make up an effective professional development programme. These characteristics suggest that professional development is more than a sequence of isolated workshops or in-service days; rather it is a process of putting knowledge into practice within a community of actively engaged practitioners. Although many of these characteristics are inter-connected, each one will be briefly discussed now.

Enhancing teachers' content knowledge and pedagogical knowledge

Guskey (2003) in his analysis of characteristics of effective professional development found the characteristic that was most often mentioned was "enhancement of subject and pedagogical knowledge". Guskey states that, "helping teachers to understand more deeply the content they teach and the ways pupils learn appears to be a vital dimension of effective professional development" (p. 749). Over the last decade there has been an increase in research focusing on the effectiveness of professional development programmes that are concerned with both subject knowledge, and an understanding of how children learn that subject matter. Kennedy (1998) reviewed a number of research studies on the impact of teachers' professional development programmes, on pupils' achievement. Her study found that professional developments that concentrated on subject matter and how pupils learn it had the greatest positive impact on pupil learning. Cohen and Hill (1997) working with mathematics teachers' in the USA, reported that when teachers are given opportunities to participate in professional development concerned with content-specific pedagogy linked to the new curriculum they are going to teach, their practices more closely resembled those envisaged by the new curriculum structure. Also, their pupils' achievement was significantly higher. The American Educational Research Association (2005) emphasized the importance of professional development that incorporates how pupils learn particular subject matter – having knowledge of how pupils learn a particular topic leads to teacher behaviour change and improved pupil achievement. These findings are very relevant to the present study for a number of reasons: (1) professional development will be more effective if it is specifically concerned with enhancing teachers' knowledge of science subject matter that is found on the curriculum, and (2) because of the inquiry-based and constructivist nature of the Irish primary science curriculum, teachers need to have an awareness of how learners learn science, including pupils misconceptions and prior ideas.

On-going and sustained professional development

A common characteristic of effective professional development considered throughout the literature is the necessity for on-going and sustained support for teachers when they go back to their schools to put their professional development objectives into practice (Garet et al., 2001; Guskey, 2003; Hogan et al., 2007). Two studies, Garet et al. (2001) and Supovitz and Turner, (2000) provide direct evidence that the length of professional development is connected to the depth of teacher change. Working with 1,000 mathematics and science teachers in the USA, Garet et al. (2001, p. 933) found that long term prolonged professional development was more likely to have an influence on improved teacher knowledge and skills, and pupil attainment, than shorter professional development programmes. The researchers reported that teachers who experienced follow-up (e.g. activities reflecting on and learning from classroom practice) were more likely to state that their teaching had improved, than teachers who did not have follow up. Supovitz and Turner, (2000) carried out a large extensive study (5000 teachers in schools across the United States) regarding the minimum time needed for professional development to lead to change in teachers' classroom practice. They found teachers with 80 or more hours of professional development, employed inquiry-oriented teaching practice in science, significantly more frequently than other teachers (p 973). After 160 hours of professional development, teachers reported changes in classroom culture. Supovitz and Turner concluded that there was "a strong and significant relationship between professional development and teachers' practices and classroom cultures" (p. 975). Results from both studies clearly illustrate that *time* is an important requirement for professional development and that most traditional professional development programmes which tend to be short in duration, will not be very effective at changing teachers' classroom practice. It takes considerable time for teachers to comprehend new information and resources, to change their views and attitudes, and then their classroom practice.

On-going and sustained professional development for teachers when they return to school can provide them with time and support to develop clear connections between the ideas presented and their classroom experiences, contributing to real change and continuous improvement. An important feature of this support could be the development of a network of communication among the teachers and between professional development facilitators and teachers i.e. a professional learning community. This is especially relevant for teachers in small rural schools.

Active engagement by participants

Teachers will probably use what they learn when professional development is centred on their concerns and is relevant to their particular contexts and needs. However, most traditional professional development programmes tend to be context-independent and do not focus on the practical and relevant issues for participants i.e. teacher-identified needs. Professional development is more significant to teachers once they take ownership of its content and process (King & Newman, 2000). Teachers are likely to experience a greater sense of participation in the professional experience when they help in the design of their own learning. Rose and Reynolds (2006) succinctly capture the essence of this point:

> Teacher ownership of CPD is a feature of highly effective schools, as are creative CPD opportunities. Teachers selecting their own CPD focus or activities can have a hugely positive effect on motivation, enthusiasm and take-up of any new ideas with compulsion being seen as having negative consequences in the impact of CPD (p. 222).

Ownership of professional development can be very empowering for teachers – they realise they have knowledge and skills worth sharing, and they share these with colleagues. Hawley and Valli, (1999) claim that professional development that involves teachers in the planning "increases the likelihood that individuals will feel and be freer to engage in reflective practice and experimental learning" (p. 140).

As discussed in Chapter Two (section 2.2.3), over the past two decades researchers have discovered more about how people learn and the strategies needed to support that learning. In science education this involves the learner experiencing science through active inquiry, recognising misconceptions and changing prior ideas that block understanding (Driver et al. 1985). It is important then that professional development programmes should engage teachers as active learners. By actively engaging participants in professional development and involving them in the ownership of the process, the programme connects professional development to their classroom practice. Teachers learn the science their pupils are expected to learn, and in much the same way.

Job-embedded

Traditional professional development is typically organised as isolated activities outside of the school setting and external to the on-going work of teaching. It tends to be based on the notion that participating teachers will use the knowledge and skills presented back in their classrooms without further support. Many educationalists (e.g. Little, 1993; Loucks-Horsley et al. 2003) agree that successful professional development must be school-based, rooted into the daily life of the classroom and engrained in the questions and interests of teachers. Hawley and Valli, (1999) emphasise that the most successful professional development occurs in the school when it is dealing with issues that concern the school. Lieberman (1995) maintains that the definition of professional development needs to be broadened to include “authentic opportunities to learn from and with colleagues inside the school” (p. 591). Unlike most traditional forms of professional development, job-embedded professional development offers opportunities for feedback, reflection, and discussion. It expands the scope of what counts as professional development and takes a variety of forms including discussion groups, coaching, mentoring, action research, curriculum development, and collaborative lesson planning. Job-embedded professional development can effectively address the real needs of teachers and pupils. It can encourage teachers to become members of a professional school community in which members learn from one another by engaging in professional dialogue around their classroom practice - exchange ideas, resources, advice and support. In order for teachers to change their classroom practice and learn to teach in new ways, professional development must be redefined as a central part of teaching. Hogan et al. (2005) argue:

> If continuing professional development is to become a distinguishing feature of teaching in the 21st century, the idea that it is somehow an “add on” must yield to the much more promising standpoint that views it as an essential dimension of the teacher’s normal working life. (p. 3)

Collaborative and collegial professional development

One of the major limitations of traditional models of professional development (see section 5.2) is the lack of opportunities they provide teachers with, to work actively and collaboratively. Increasingly, professional development has become focused on breaking down the professional isolation of teaching and building up of a professional culture in schools. A truly collaborative approach to professional development involving an active role for teachers including their experiences and voices, can help breakdown teacher insulation and isolation by providing opportunities for teachers to work together, exchange ideas and resources, and reflect on their classroom practices. King and Newmann (2000) noted that, “Teacher learning is most likely when teachers collaborate with professional peers, both within and outside their schools, and when they gain further expertise through access to external researchers and program developers” (p. 576).

Little (1990) warns against forms of collegiality that involve assistance, sharing and storytelling, stating that these are superficial examples of collaboration. Fullan and

Hargreaves (1996) advise against *comfortable collaboration*, where the seclusion of the teacher's classroom is safeguarded and there is no meaningful examination of issues of teaching and learning. Malone and Smith (2010) argue that professional development that encourages the development of a culture of *meaningful* collaboration (one which encourages teachers to discuss issues that affect their day to day classroom practice, as well as sharing resources and ideas) can be very effective in bringing about changes in teacher's classroom practice. They maintain that developing such a culture involves a number of strategies including the building up of trust over time and involvement of participants in the decision making process – encouraging them to believe in the significance and relevance of what they are doing. Furthermore, Malone and Smith stress that a major benefit of meaningful collaboration, is that it enables participants themselves to see insulation and isolation as a restricting feature of their professional lives (p. 111). Most significantly, for a study working with teachers in small 2/3 teacher rural schools, meaningful collaborative professional development can provide a supportive culture where there is regular social and professional interaction between teachers, and it can actively encourage them to openly discuss their classroom practice, share visions and move forward together.

Encouraging teachers to reflect on their learning

In general, the main aim of most traditional professional development programmes seems to be the upgrading of teachers' content knowledge and skills. There is little or no emphasis on facilitating teachers to critically reflect on the new knowledge and skills they have acquired or their impact on classroom practice. Reflection is identified as a significant component of effective teaching mainly because it helps teachers to reconsider their practice to learn from their experiences and helps them to handle similar experiences in the future (Hoban, 2002, p. 62). The idea of teacher reflection as a means for enriching classroom practices is not new; it can be traced back to John Dewey, who recognised the significance of "reflective thought" in educational environments. The cultivation of critical reflection among practitioners has gained more acceptance over the last three decades or so, stemming largely from the work of Schön (1983, 1987). Schön (1987, p. 28) identified two types of reflection – reflection-in-action and reflection-on-action. Reflection-in-action, is a reshaping of "what we are doing while we are doing it" i.e. practitioners who experience a situation containing an element of surprise make almost subconscious decisions regarding the best use of their knowledge, built up from previous experiences to deal with the situation. Reflection-on-action, on the other hand is a "thinking back on what we have done" i.e. is a deliberate reflection after the experience, when practitioners examine what they did, how they did it and alternative ways of doing it. Pritchard and McDiarmid (2005) explain that, in teacher education, reflective practice is one of the main elements needed for effective teaching and professional development. They maintain that reflective practice is the considered action of "reviewing and critically thinking about practice with the purpose of increasing learning opportunities for pupils and teachers" (p. 433). Darling-Hammond and McLaughlin (1995) stress that professional development must offer "occasions for teachers to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy and learners" (p. 597).

Brookfield (1995) emphasises that critical reflection is an important aspect in the development of reflective thinking. Brookfield maintains it is possible for teachers to probe personal, political and social "assumptions" regarding what it means to be a reflective practitioner and be able to make informed decisions about one's teaching practice. He presents a useful approach for achieving this – looking at teaching through the use of four "critically" reflective lenses (pp. 29-39) – our autobiographies (own view) as teachers and learners, our pupils' eyes, colleagues' perceptions, and relevant theoretical perspectives in educational literature. Ingvarson et al. (2005) maintain that opportunities to reflect on and practise new ideas and receive feedback (from a colleague or mentor) on performance are vital characteristics in effective professional development (p. 17). This links to aspects of Brookfield's "lenses" used in reflection.

Brookfield (1995) also suggests that there are three cultural barriers that discourage teachers from being critically reflective:

- Culture of silence – teachers rarely discuss their classroom practice in public
- Culture of individualism – teachers usually work in isolation away from colleagues
- Culture of secrecy – self-disclosure will only occur if it is not seen as a sign of weakness and only with people who teachers trust.

(pp. 248-249)

This suggests that collaborative critical reflection does not come naturally to most teachers, so it is important that teachers are presented with appropriate opportunities to break down the more restrictive features of inherited professional cultures. Professional development programmes that incorporate collaborative reflection can contribute to this, by engaging teachers as a group working together in a supportive environment. The group can generate more ideas about classroom practice and provide greater clarity of issues than any one individual can. In terms of the present study, if teachers are given the opportunity to reflect on their own teaching of science, they may possibly develop a deeper understanding of their knowledge of science teaching and student learning.

Shanker (1996) sums up the characteristics needed for effective professional development very well when he states:

> For professional development to be effective, it must offer serious intellectual content, take explicit account of the various contexts of teaching and experiences of teachers, offer support for informed dissent, be on-going and embedded in the purposes and practices of schooling, help teachers to change within an environment that is often hostile to change, and involve teachers in defining the purposes and activities that take place in the name of professional development (p. 223).

5.3 Models of professional development

A key aim of this study is to develop a model of professional development that can be used with primary teachers in 15 small rural schools, in order to improve the teaching and learning of primary science. There is an increasing recognition among educators that there are no "one size fits all" models for professional development. Guskey (1995) maintains that there is no best model of professional development, stressing that issues of context are crucial in deciding which model to use. However, as discussed in the previous section there are a number of recognised principles to guide effective professional development, no matter what model is used.

The professional development literature is filled with numerous models that offer a variety of approaches to professional development of teachers. For example, Sparks and Loucks-Horsley (1990) classified professional development into five models. These include: training, observation/assessment, individually guided professional development, Involvement in a development or improvement process, and inquiry. In 1998 Loucks-Horsley, Hewson, Love and Stiles identified fifteen models for professional development.

Kennedy (2005) categorised professional development according to its purpose and effects on teachers' practice. She developed a spectrum of nine models and classified them as *transmissive, translational* or *transformative*. These models are selected for discussion here because of their widespread application in many countries including Ireland. The nine models (Kennedy, 2005 pp. 237-247) are outlined below:

Training model: This model has been the most common and major form of professional development for teachers. The training model involves teachers attending workshop sessions focusing on skills "delivered" to teachers by "experts". The agenda is regulated by the "experts" and places teachers in a passive role while increasing their knowledge. A major criticism of the training model is its lack of association to the classroom situation in which participants work. In spite of its weakness, the training model is recognised as an effective way of introducing new knowledge.

Award bearing model: Is generally carried out in combination with higher education institutions, it usually depends on the achievement of award-bearing programmes of study that are authenticated by a higher education institution. Kennedy argues that, "this external validation can be viewed as a mark of quality assurance, but equally can be viewed as the exercise of control by the validating and/or funding bodies" (p. 238).

Deficit model: This model attempts to address the supposed shortcomings of individual teachers, it may not be good for teacher confidence. The deficit model fails to "take due cognisance of joint responsibility i.e. that the system itself is not considered as a possible reason for the perceived failure of a teacher to demonstrate the requested competence" (p. 239).

Cascade model: This model involves teachers attending "training events" and then distributing the information to their colleagues. It is relatively cheap in terms of resources and is used in situations where there are limited resources. A limitation of this model is that "what is passed on in the cascading process is generally skills-focused or knowledge-focused, but the model rarely focuses on attitudes and values" (p. 240).

Standards-based model: This model presumes that there is a system of efficient teaching, and is not amendable in terms of teacher learning. The standards-based model "belittles the notion of teaching as a complex, context-specific political and moral endeavour". It also has a deep reliance on a behavioural viewpoint of learning, "focusing on the competence of individual teachers and resultant rewards at the expense of collaborative and collegiate learning" (p. 241).

Coaching /mentoring: The defining characteristic of this model is the significance of the one-to-one relationship, usually between two teachers, which is designed to support professional development. Key to this is the development of a non-threatening relationship to enhance discussion between teachers within the school context. The mentor should possess good communication skills.

Community of practice model: Unlike the coaching/mentoring model, the community of practice model "generally involves more than two people, and would not necessarily rely on confidentiality" (p. 244). The combination of a number of individuals' knowledge is the central foundation for the formation of new knowledge.

Action research model: This involves individuals themselves investigating aspects of their own teaching practice with a view to improving it i.e. it is relevant to the classroom. It allows teachers to ask vital questions of their classroom practice. Collaborative action research "provides an alternative to the passive role imposed on teachers in traditional models of professional development" (p. 245). It encourages teachers to see research as a process rather than merely an outcome of someone else's endeavours.

Transformative model: This model involves the integration of various practices and settings that are taken from other preceding models described above. In this sense, "it could be argued that the transformative model is not a clearly definable model in itself, rather it acknowledges the variety of different circumstances needed for transformative model in itself; it recognises the range of different conditions required for transformative practice" (p. 246).

Kennedy lists the models in increasing order of capacity to be transformative in purpose. That is also the order that has been used above. She defines transformative capacity as being the model's potential to increase "capacity for professional autonomy" (p. 246). Kennedy maintains, the models that have the least capacity to generate transformative action have the transmission of knowledge as their main aim (see table 5.1). These include the training model, the award-bearing model, the deficit model, and the cascade model. This type of professional development does not support professional autonomy. Transitional models such as the standards-based model, the coaching/mentoring model, and the community of practice model have the capability to support either a transmissive or a transformative scheme. Table 5.1 shows two models that have transformative action as their purpose; they are the action research model and the transformative model. Both give teachers the capacity to decide their own learning pathways i.e. support considerable professional autonomy.

Table 5.1: Kennedy's spectrum of CPD models

Model of CPD	**Purpose of model**
The training model The award-bearing model The deficit model The cascade model	Transmission
The standards-based model The coaching/mentoring model The community of practice model	Transitional Increasing capacity for professional autonomy
The action research model The transformative model	Transformative

As shown above, there is an extremely wide range of professional development models, some suited to the needs of the individual teacher, while others meet the demands of the school system. For example, a *transmissive* model (training model) would suit those who seek a product based outcome. On the other hand, a transformative model (action research) is suited to those who seek a process approach to professional development.

The literature reviewed in section 5.2 indicates that approaches to professional development that address teacher personal development and social development, as well as professional development, are more likely to lead to transformative change. As stated in Chapter One, a key aim of this study is to support teachers in enhancing their science content knowledge and pedagogical knowledge, breaking down professional isolation, and changing their classroom practice.

The intervention model designed for the present study combines aspects from the range of models discussed above to suit the needs of the teachers participating in the study – emphasising personal, social and professional development of teachers. Participants are given the opportunity and support to:

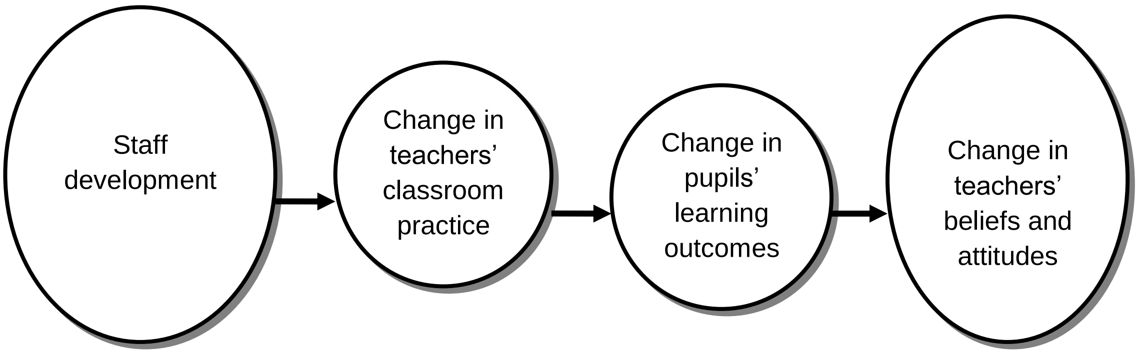
- Enhance their science content knowledge and pedagogical knowledge and skills (*transmissive*);
- Discuss new ideas regarding teaching and learning science with other teachers (*transitional*);
- Implement new ideas and strategies in their classroom practice e.g. action research (*transformative*);
- Reflect on changes and provide feedback to other participants (*transitional*).

An effective professional development programme may look very different from place to place. It is designed to tackle specific needs and to fit into the context in which it will be implemented. The researcher believes the proposed model for this study will address the needs of the participants and will likely lead to transformative change. Details of the model used are found in the next chapter.

5.4 Professional development and transformations in teachers' attitudes and practices

As discussed in Chapter Four, designing professional learning opportunities for teachers regarding implementing a new curriculum, or innovative approaches to teaching science, needs deliberation of a number of factors, such as teachers' knowledge of science, and their attitudes to teaching science. Guskey (2002) argues that the primary goal of professional development is to generate transformation in teachers' classroom practice, in teachers' attitudes and beliefs, and in the learning outcomes of pupils. Of particular importance to this study is the interdependence between these outcomes and the sequence in which they occur. Many professional development approaches (see section 5.2) have attempted to change teachers' attitudes and beliefs with the notion that this will lead to changes in their classroom practice. Implicit to this approach is the expectation that this, in turn, will result in improvements in pupil performance. In a critical examination of this model, Guskey (1986) carried out a research study comparing less than effective professional development programmes, with those that had resulted in significant changes in teachers' attitudes and behaviour. From his research he found, a major feature influencing teacher change was when they experienced positive changes in their pupils' learning outcomes, as a result of the teacher's implementation of the skills or strategies attempted from the professional development programme. "Significant [enduring] change in teachers' beliefs and attitudes is likely to take place only *after* changes in pupil learning outcomes are evidenced" (p. 7) see figure 5.1. Guskey suggests it is not the professional development as such, but the experience of successful implementation that brings about changes in teachers' attitudes and beliefs. He maintains "change in teachers' beliefs and attitudes are primarily a result, rather than a cause, of change in the learning outcomes of pupils" (Guskey, 1986, p. 9). Furthermore he states "in the absence of evidence of positive change in pupils' learning, it suggests that significant change in the attitudes and beliefs of teachers is unlikely" (Guskey, 2002, p, 384).

Figure 5.1: Model of process of teacher change (Guskey, 1986)



Guskey recommends three guiding principles necessary in the planning of effective professional development programmes: (a) acknowledge that change is an on-going and complicated process; (b) ensure that teachers obtain frequent feedback on pupil learning progress; and (c) provide continued follow-up, support, and pressure (p. 387). Guskey's approach seems to offer educationalists an optimistic perspective on the potential of professional development regarding changing teachers' beliefs and attitudes using a linear representation of a much more complex process of teacher change.

Recognizing the complexity of teacher change, Clarke and Hollingsworth (2002, p. 951) propose what they call "the interconnected model of teacher professional growth".

Their model of teacher change is cyclical rather than linear, and assumes that "reflection" and "enactment" are the mediating processes by which change in one domain leads to change in another. The four domains, which impact on change include:

- the external domain – sources of information, stimulus or support;
- the personal domain – knowledge, beliefs and attitudes;
- the domain of practice – professional experimentation;
- the domain of consequence – salient outcomes.

(Clarke & Hollingsworth p. 951)

Changing teachers' classroom practice is a complex and challenging process. These two models (Guskey, 1986; Clarke & Hollingsworth 2002) can make a significant contribution to the present study by providing a way of thinking about teacher change that takes into account the multifaceted nature of teaching and learning. They can also provide a useful framework for designing, analysing and evaluating the professional development programme. Most importantly for this study, these two models show that factors such as teachers' knowledge, beliefs, practices and pupil outcomes should be taken into consideration when evaluating the impact of professional development. Significantly, Clarke and Hollingsworth describe reflection as a "mediating process" which plays an important part in involving teachers in an examination of their learning and their teaching practice (p. 951).

5.5 Evaluation of professional development

Professional development needs to satisfy the demands of policy makers and funders, as well as developing teacher subject knowledge and pedagogy. In a time of tightening budgets, policy makers want to know if their money is being well spent – see evidence of the quality and/or effectiveness of the CPD. This makes effective evaluation of CPD more imperative than ever. Through evaluation one can:

- Improve the quality of the programme – make on-going adjustments to the programme to increase the chance of the programme achieving its objectives;
- Determine whether or not the programme is achieving its goals.

Rose and Reynolds (2006) argue that, "teachers often cite the need for CPD to be useful, relevant and appropriate if they are to take valuable time out of their classrooms. However, the impact of CPD is rarely assessed over the long term, and is often based on self-reports by teachers of the CPD experience itself, rather than the outcome." (p. 222). Furthermore, they emphasise that evaluation is not inclined to distinguish between the different purposes of CPD, or take account of the envisioned outcomes. Guskey (2002) argues that traditionally, educators have not paid much attention to evaluating their own professional development efforts. Furthermore, he states "many educators understand the importance of evaluation for event driven PD activities such as workshops...but forget the wide range of less formal, on-going, job-embedded PD activities" (p. 45). Guskey (2000) cites three major mistakes in evaluations of professional development that have made them inadequate and ineffective:

1. They focus on "documentation" rather than evaluation and merely consist of summarising the events taken on as part of the professional development programme.
2. They are too shallow and do not address meaningful indicators of success.
3. They are too brief and extend over too short a time period. (p. 8**)**

Piggot-Irvine (2006) argues that evaluation of professional development programmes is essential, and rigorous data-based evaluation must be taken to establish whether changes in outcomes have resulted from the programme (p. 484). She identifies a number of factors needed for the effective evaluation of professional development programmes:

- Designing evaluation expectations prior to programme implementation;
- Incorporating evaluation expectations within the professional development plan;
- Using rigorous data-based information to determine the effectiveness of the programme;
- Determining whether attitudes and practices of participants have changed for the better;
- Determining whether the changes are manifest in classroom and school practices.

(p. 486)

It is fundamental to understand what the participants actually learn from their experience, and how they apply it to their teaching and their pupils' learning.

Framework for evaluating CPD

There are several models of evaluation of professional development found in education. In a seminal piece of work *Evaluating Professional Development* Guskey (2000), having carried out a thorough review of evaluation models in professional development, proposed his own model for evaluating professional development. Guskey's model is hierarchical in nature – judging the responses of participants, assessing learning by showing impact on classroom practice and by measuring pupil learning outcomes. It consists of evaluation at five levels, as shown in table 5. Each level builds on the one before it. For each of the five levels, Guskey sets out what questions are addressed, how information will be drawn together, what is evaluated or assessed, and how the information will be used (p. 48).

Table 5.2: Guskey's five levels of Professional Development Evaluation

Level of Evaluation	**Description**
1. Participants' reactions	Did the participants find their experience useful and enjoyable?
2. Participants' learning	Did the participants increase their knowledge/skills?
3. Organisational support and change	Were participants supported in the implementation of their new learning?
4. Participant use of new knowledge and skills	Are participants implementing new knowledge/skills in their classroom?
5. Pupil learning outcomes	Did the learning have an impact on or affect pupil achievement?

While Guskey's (2000) study is largely concentrated on American research, the circumstances in Ireland are comparable in a number of ways. In the Irish context, evaluation of professional development is usually summative in nature, occurring immediately after a workshop (Malone & Smith 2010) – teachers complete a form asking questions concerning delivery, content and meeting objectives. Doyle (2009) maintains the evaluation of the last two of Guskey's levels, i.e. "participants' use of newly acquired knowledge and pupil learning outcomes, still seem to be the most elusive and can only be evaluated with a closer collaborative partnership between trainers, teachers and the organisations in which they work" (p. 148). The model of evaluation that the present study proposes is built on all five of Guskey's levels.

5.6 Professional development of teachers in small rural schools

Traditionally, the preferred option of classroom structure in primary school systems throughout the world has been the single-grade class arrangement, where pupils of the same age are grouped into classes regardless of other factors pertaining to levels of attainment (Little, 1995). Mulryan-Kyne (2005) states "the bringing together of large groups of same-age children for instruction by one teacher in the one classroom was generally held to be the most administratively and economically expedient way of providing education for the maximum number of children" (p. 1). However, in a large number of primary schools, single-grade classes are not an option. For example, in many rural areas, small pupil numbers make single-grade teaching unworkable. The option usually considered in such situations is the multi-grade class structure. This involves one teacher teaching pupils of different ages, grades and abilities in the same class. Multi-grade classes are common in the educational systems of most developed and developing countries throughout the world. They are a significant feature of rural primary education in the Republic of Ireland. Over 40% of primary school classes in the Republic of Ireland are multi-grade (DES, 2004).

Many of these schools may have only two or three teachers who have to teach multi-grade classes, as well as cope with all the demands that a school presents e.g. maintain a breadth and quality of curriculum comparable to that found in bigger urban schools. Rural isolation limits opportunities for professional contacts with colleagues. Sigworth and Solstad (2001) suggest there are two reasons why fears have been expressed that teachers in small schools may suffer professional isolation: (1) the size of the school may mean that there are only one or two colleagues with whom a teacher can exchange ideas and advice, unlike the situation in a large school, where there are more colleagues; (2) traditional in-service training is usually provided at centrally or regionally organised courses, meaning the teachers are often required to travel long distances. Teachers in small remote schools are often a long way from locations of in-service provision such as colleges and teacher centres. It may be impossible for a teacher to travel such distances to reach an in-service centre, especially in harsh weather conditions (p. 6). Furthermore, they argue that this isolating factor can only be overcome "if the providers are able to take account of the circumstances of their small remote schools when planning appropriate forms of in-service education, including networking arrangements" (p. 6). Sigworth and Solstad (2001) emphasise "if teachers in small rural schools are unable to obtain advice and find it difficult to update their professional knowledge, it is likely that the education which they provide for their pupils will be less effective than it could be" (p. 6).

School clustering

Over the last two decades, there has been increasing recognition of the need for teachers in small rural schools to develop contact with teachers in similar schools, in order to exchange information, identify common concerns and problems and cooperate in developing solutions to them (Giordano 2008). MacNeil, (2004) argues that the traditional form of in-service teacher professional development has been proven to be unsustainable and have rarely translated into instructional gains. He suggests that school-based or cluster-based in-service programmes provide an alternative, effective, relevant and cost-effective means of providing professional development that will reach all teachers, especially those in rural areas (pp. 3-4). According to Sigworth and Solstad (2001) school clusters in remote rural areas have four main aims:

1. To overcome the isolation which their teachers can experience;
2. To amplify the range of expertise at their disposal;
3. To provide a means of establishing common interests and needs;
4. To foster cooperation.

From the researchers' experience of working with school clusters on the *Teaching and Learning for the 21st Century* (TL21) Project (2007), teacher discussion groups are a key feature within school clusters. They can act as forums, in which teachers can exchange ideas and information, discuss pedagogical practice, identify their pressing problems and plan joint solutions.

Professional learning communities

One of the key aims of this study (outlined in Chapter One) is to assist schools in becoming professional, independent learning communities through professional development. Professional learning communities are increasingly more and more being seen as an effective channel for teacher learning and professional development. The literature provides several definitions of professional learning communities. However, the definition of a professional learning community most relevant to the present study is that of Stoll et al. (2006):

> inclusive group of people motivated by a shared learning vision, who support and work with each other...and together learn new and better approaches that will enhance all pupil learning (p. 222).

Studies by Hogan et.al (2007), and Vescio et al., (2006) have shown the positive impact of professional learning communities on teachers' personal and professional growth. Working together in a community of peers can offer opportunities for teachers to reflect on their teaching practice and learn from one another in ways that will bring about enhanced pupil achievement. This type of collaboration is seldom realised in more traditional types of professional development. Bolam et al. (2005) detail characteristics that all effective professional learning communities share in common, they include: reflective professional enquiry, mutual trust, respect and support, shared values and vision, collective responsibility for pupils' learning, and collaboration focused on learning and openness.

5.7 Summary of salient issues

There is a growing recognition that "traditional" methods of professional development such as "one-off" workshops and short modular courses are ineffective at bringing about significant or enduring change in classroom practice. In order for professional development to be effective and bring about significant change, a number of characteristics need to exist, these include: active teacher involvement, job-embedded provision, involving collaborative, on-going and sustained reflective practice. These characteristics provide teachers with experiences that are connected, coherent and on-going, and support teacher personal development and social development as well as professional development. There are numerous models of professional development for teachers. However, there is no "one size fits all" model. If a model is to be effective it needs to attend to the particular needs of the participants and adapt to the environment in which it will be carried out.

Evaluation is an imperative feature of effective professional development, it can ascertain whether or not a programme is meeting its objectives, ensure approval of participants, and act as a means of improving future provision. The purposes of evaluation can be best accomplished by gauging the responses of participants, assessing learning through verifying the impact on classroom practice and pupil learning outcomes.

Clustering of schools, especially small rural schools, provides teachers with opportunities to use group processes such as group reflection, collaboration and professional dialogue thus, overcoming some of the challenges of working in isolated areas.

The research findings reviewed in this chapter related to designing and carrying out effective professional development programmes. Factors impacting on professional development have provided guidance in moving towards implementing and evaluating the professional learning intervention programme to be used in the present study.

The first five chapters in Part I of this thesis provided a richly informed framework including: important developments in policy and practice in primary science education, internationally and in Ireland, and an examination and analyses of the literature and research that forms the framework and rationale for addressing the research questions in this study. Part II of the thesis is concerned with the main premise of this research study i.e. the impact of the professional development programme on teachers' attitudes and confidence in teaching science, and pupils' attitudes towards learning science. The next five chapters will describe and analyse how the intervention programme was carried out, probe the extent to which the programme was successful in achieving its goals and suggest areas of consideration by policy makers for future work in the area of continuing professional development.

Chapter 6
Methodology

Introduction

This chapter explains the methodology that was used to complete this research study. It presents the design of the study including the justification for the research procedure employed, (mixed methods and action research) and the methods of data collection. Section 6.1 recalls, in summary the context of the study. This is followed by sections 6.2 and 6.3 which give an overview of the research philosophy adopted and research design chosen. Section 6.4 provides an overview of how evaluation of the Western Seaboard Science Project was carried out. Section 6.5 provides a detailed description of the data collection strategies, instruments used and rationale for their use. Section 6.6 describes the intervention model used in the study including the four key features fundamental to the programme (active participation, meaningful collaboration, continuity and feedback) and the principles underlying the workshop approach of the programme. This is followed by three sections on quality assurance in data collection: the role of the researcher (section 6.7), triangulation (section 6.8) and inter-rater reliability (section 6.9). Ethical issues arising from the conduct of the research are considered in section 6.10.

The following underlying assumptions, which have been elucidated and critically examined in previous chapters, have strongly influenced the researcher to carry out this study.

- Primary teachers' confidence, competence, and attitudes towards teaching science are each crucial factors in the successful introduction of the primary science curriculum into Irish primary schools;
- Evidence from international research literature suggests that primary teachers' confidence, competence and attitudes towards teaching science are a world-wide concern;
- Teachers' attitudes and beliefs in relation to science itself, affect their classroom practice and have a critical influence on the attitudes of their pupils;
- Professional development for teachers can bring about transformation in their classroom practices and contribute to higher learning outcomes for pupils;

- To be effective, professional development needs to be extensive, on-going, well-focused and collaborative.

The main aim of this study is to develop an innovative model of professional development in science education with primary teachers in 15 small rural schools, in order to enhance the teaching and learning of primary science. There were four objectives that guided this research. These were based upon the above assumptions. The researcher sought to achieve the following objectives:

1. Investigation of the extent to which this model can help bring about improvements in confidence, competence, attitudes and levels of knowledge among primary teachers, where the teaching of science is concerned;
2. Investigation of the extent to which pupils' attitudes towards science are productively influenced by changes in teachers' confidence and pedagogical approaches;
3. The breakdown of the insulation and isolation that teachers experience in their day-to-day professional lives and the development of sustainable learning communities between the participating schools – developing *meaningful* collaboration using a participatory and sequenced workshop model, a Virtual Learning Environment and individual school visits;
4. Investigation of what features of this model could be incorporated into continuous professional development more widely.

6.1 Context of the study

An experimental professional development project for teachers of primary science was organised for a two-year period under the auspices of the Irish American Partnership (IAP) and the Government Department of Education and Skills (DES). The "Western Seaboard Science Project" (WSSP) was set up and concentrated on rural schools in the West and North-West of Ireland. A key feature of the project's design was the provision of funding for a detailed evaluation of the effects of its interventions on the quality of teaching and learning of science in Irish primary schools. The intention was that the findings of this evaluation should contribute to national policy on professional development for teachers of primary science. The research dimension of the project forms the basis for the programme of work for this research study.

WSSP was organised by the Biology Department of St Patrick's College Dublin. Selection of participating schools was carried out by the DES and the IAP. The sample population consisted of 24 practising teachers and approximately 281 pupils from 15 small rural primary schools (two/three teacher) in the West and North-West of Ireland. Even though the number of teachers participating in the study was limited to 24, it was possible to select teachers with a range of experience and of both genders. The schools were grouped into three clusters of five schools in Galway, Donegal and Mayo. The participants in this study consisted of seven male and seventeen female teachers, with teaching experience ranging from 2 years to 37 years. All the participating pupils were drawn from 4^{th}, 5^{th}, and 6^{th} classes (multi-grade), with an age range of 9 -12 years.

6.2 Research philosophy adopted

The traditional research methodology used in education is the empirical approach. This approach relies, in the main, on quantitative analysis of data, such as, classifying and measuring behaviour. A major criticism of the empirical approach is that education encompasses interpersonal relationships that are not readily encapsulated in quantitative terms. Over the past three decades or so qualitative research has emerged as an important form of inquiry as researchers seek to examine the context of human experience (Doyle et al., 2009, p. 177). Qualitative research methodologies and methods that have emerged include ethnography, phenomenography, and action research. The rise of qualitative research approaches has led to a great debate in social research methodology concerning the use of qualitative and quantitative methods (Tashakkaui & Teddie, 1998). The advantages and disadvantages of both methods led to advocates of each arguing the dominance of their method over the other. Lund (2005) claims proponents of quantitative methods argue that their data are scientific, credible and rigorous, whereas qualitative data are usually more vulnerable to subjectivity and bias. Advocates of qualitative research maintain that their data are comprehensive, contextual and sensitive, whereas quantitative data ignore the non-measurable variables, which may be very important.

Richard Pring (2000) calls attention to the ample body of texts and theses in educational research that distinguish between quantitative and qualitative research and that demonstrate, in most cases, a loyalty to one or the other (p. 248). He rejects what he describes as the "False Dualism" between qualitative and quantitative research and develops an alternative position that allows him to assign distinctive roles for both methodologies: “the qualitative can clear the ground for the quantitative – and the quantitative can be suggestive of differences to be explored in a more interpretive mode” (p. 259). Over the past two decades, researchers such as Creswell (2003), Johnston and Onweuegbuzie (2004) and Tashakkori and Teddlie (1998) have championed using features of both quantitative and qualitative methods in the same study i.e. a “Mixed Methods approach” to research. Patton (2002) asserts that researchers: “need to know and use a variety of methods to be responsive to the nuances of particular empirical questions and the idiosyncrasies of specific stakeholder needs” (p.585). Mixed methods research is viewed by many as a legitimate alternative to qualitative and quantitative research (Doyle et al., 2009).

Many social science and education researchers have begun to support pragmatism as a suitable paradigm for mixed methods research (Johnston and Onwuegbuzie 2004; Patton 2002). Tashakkaui and Teddie (1998) state that pragmatism calls for “whatever philosophical and/or methodological approach that works for the particular research problem under study” (p. 5). Creswell (2003) argues that pragmatism is pluralistic, based on a rejection of a forced choice between positivism and constructivism, and that pragmatist’s link the choice of approach directly to the purpose and nature of the posed research questions. Pragmatism allows for the mixing of methods within a specific study, if the researcher believes it will help make the data collection and analysis more accurate (Rocco et al., 2003 p. 21). Tashakkaui and Teddie (1998) maintain that for researchers, pragmatism holds up well to scrutiny when compared to other competing alternatives to the question of what is the best paradigm for mixed methods research. This study encompassed a pragmatic approach for the following reasons:

- It supported the use of both qualitative and quantitative methods in this study – enhancing validity, and providing checks and balances in analysing facts and perceptions;
- It considered the research question to be more significant than either the method or the paradigm that underlies the method.

6.3 Research design

The research design in this study was influenced by (1) the type and amount of data being sought and the kind of interventions being made to promote productive change, (2) the relationship of the researcher to the programme, and (3) the successful experience of the researcher in a previous professional development programme. With these factors in mind the study uses a combination of research approaches including questionnaires, interviews, monitoring, and a strong element of action research. The action research is carried out by the participating teachers at the level of classroom practice, and by the researcher at the level of continuing professional development.

The main purposes of this study can be summarised as: (a) investigating the impact of an innovative, participatory model of professional development in science education on primary teachers' attitudes to science and confidence in teaching science, and (b) exploring whether or not pupils' attitudes to school science were influenced by a transformation in teachers' classroom practice, and in teachers' attitudes and beliefs. The focus of the study is complex, suggesting that careful consideration should be given to the selection of appropriate research approaches. This required the researcher to gather data in a range of organised ways, allowing the researcher to test the effectiveness of the WSSP model in developing teachers' attitudes to science and teaching science. The study also required the researcher to gain a deeper understanding of the varied experiences the participants encountered during the research, such as their confidence levels, perceptions and feelings, and to explore unexpected patterns and relationships that emerged.

The relationship between a researcher and the research scenario is a key consideration when contemplating an appropriate research design. The researcher in the present study is very closely involved with the intervention programme at a number of levels: as designer of the actual programme; as facilitator of all the project's workshops; and, as support (critical friend) for participants in between workshops (see section 6.7 for a detailed account of the role of the researcher).

From 2005 to 2007 the researcher was the Research and Development Officer with the 'Teaching and Learning for the 21st Century' (TL21) professional development project (Hogan et al. 2007). The approach taken in the TL21 project was largely action research in nature. One of the most effective features of the approach used in the TL21 project was the participatory character of the project's workshops and the informal, yet professional contacts sustained by participants and researchers (Hogan et al. 2007, p.31). Findings from the project showed that an action research approach was successful in addressing a number of the essential features of effective professional development discussed in Chapter Five, including: active participation, meaningful collaboration, building of interpersonal trust, teacher reflection and feedback. With these factors in mind, the approach which has been adopted in this study borrows a great deal from the action research procedure used in the TL21 project, using a combination of quantitative and qualitative methods as an appropriate framework.

6.3.1 Action Research

Action research in simple terms is "a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out" (Carr & Kemmis 1986, p. 162). Ferrance (2000) points out "through action research, teachers learn about themselves, their pupils, their colleagues, and can determine ways to continually improve" (p.14).

As outlined in Chapter Five (section 5.2), a major drawback of traditional models of professional development is the inactive role of teachers in the process and their difficulty in implementing ideas and concepts that can be far removed from their classroom practice. Action research on the other hand, provides a more active role for teachers in their own development and recognises the important roles of teachers in decision making, based on their requirements and the requirements of their pupils. The active involvement of teachers in action research can generate forms of knowledge that is both personally relevant and meaningful to teachers, features often missing from research produced solely by "outsiders".

An action research approach that involves a dimension of teamwork (i.e. of collaboration between practitioners) provides teachers with opportunities to critically evaluate teaching and learning problems encountered in the classroom in a collaborative manner. As a methodology it encourages teachers to raise questions about theory and practice. The role of the researcher is to assist teachers to take control of and change their own work.

Within the action research field there are two main approaches, individual and collaborative. Individual action research usually involves a single teacher examining an issue in his/her own classroom. A key limitation of the individual approach is that the outcomes may not be disclosed to colleagues unless the teacher chooses to give the findings in a formal way. Collaborative action research, on the other hand, involves a group of teachers interested in addressing an issue, or range of issues, relevant to their needs. They may be supported by individuals from outside their schools such as education departments in universities. Collaborative action research can provide an effective mechanism for reducing teacher isolation by enhancing collaboration, collegiality and building professional learning communities among teachers. By seeking others views of the data collected, the process becomes more scientific. The present study uses a collaborative action research approach. While the study does not strictly follow an *observe*, *reflect*, *plan* and *act* cycle of action research, the approach is within the action research tradition.

Because action research is conducted by persons who are interested participants in the research it has often been criticized for shortcomings in its objectivity. Denscombe (2007) states “the necessary involvement of the practitioner limits the scope and scale of the research...and affects the representativeness of the findings and the extent to which generalisations can be made” (p. 131). However, proponents of action research argue against this by suggesting that action research can enhance validity by widening the base for data collection and including contextual factors – validity can be attained by the depth and variety of data collected. Reliability is achieved by triangulation of data from various sources and the thoroughness with which analysis and interpretation are carried out. Elliott (1991) recommends the following measures to help overcome the problem of objectivity:

1. The researcher should use monitoring procedures to present evidence of how well the course of action is being applied;
2. The researcher needs to employ a number of techniques which enable them to view what is happening from a variety of viewpoints.

6.3.2 Mixed methods

Owing to the nature of the research questions, a mixed methods approach, involving elements of empirical research, action research and investigative forms of qualitative research was deemed the most appropriate approach to this study. Quantitative research allows a researcher to recognise variables and evaluate their relationships in measurable and reliable ways. This is achieved through the use of formal instruments such as a questionnaire that reduces data to statistical indices. Qualitative research, on the other hand, helps the researcher to answer the “how and why” parts of the study, creating more in-depth findings. An example from the present study that illustrates this, is where teachers' views on their confidence to teaching science compared to other subjects could be gathered using a questionnaire (quantitative), and an interview could probe how or why this is the case (qualitative). Other benefits are that it is "practical", using a combination of inductive and deductive thinking, and it lets the researcher use a myriad of tools for data collection. One of the greatest benefits of mixed methods is that it provides strengths that offset the weaknesses of both quantitative and qualitative data. For example, weaknesses of the quantitative method, such as a lack of in-depth information and an inflexible process, can be counteracted by interactions of the researcher with the respondents during the interviews. Weaknesses of the qualitative method, such as excessive bias of judgment, and low population validity, can be made up by confirming with the statistical results and analyses from the questionnaires. Johnson and Onwuegbuzie (2004) suggest that a mixed methods approach "allows researchers to mix and match design components that offer the best chance of answering their specific research questions." (p. 15).

The focus of the present study is exploratory and evidence seeking – concerned with data that focuses on participants' conceptions and meanings, and determines the effectiveness of the WSSP model on teacher and pupil attitudes to school science.

6.4 Evaluation of WSSP

This section is concerned with the programme of evaluation for WSSP with reference to Guskey's (2000) five-level evaluation model. Guskey's model is hierarchical in nature – assessing the responses of participants, considering learning through evidence of impact on classroom practice and by measuring pupil learning outcomes. For each level, the evaluation method is described. The results and analysis of results are presented and discussed in Chapters Seven and Eight. Evaluation of the programme was on-going and both summative and formative in nature. The summative data was collected using questionnaires and reflection templates. Formative feedback came through interviews, open-ended questions on questionnaires and reflective discussions.

Participant reactions (Level 1)

Participant reactions were collected using a post-workshop participant reflection sheet (appendix A, p. 248). Participants were asked to comment on the strengths of the workshop, shortcomings of the workshop and suggestions for future workshops.

Participant learning (Level 2)

Participant learning was assessed using: (1) pre- and post-professional development programme participant questionnaires – affective learning goal (2) pre- and post - professional development programme cognitive questions – cognitive learning goal.

Organisational support and change (Level 3)

This was addressed in the evaluation programme, through participant interviews – participants were asked about support for programme at school level.

Participants' use of new knowledge and skills (Level 4)

This was evaluated in two ways (1) participant interview at end of programme, and (2) post-programme participant questionnaire.

Pupil learning outcomes (Level 5)

Pupil learning outcomes were addressed through a pre- and post-intervention pupil questionnaire and interviews – outcomes were affective in nature i.e. concerned with attitudes to learning science in school.

6.5 Data Collection procedures

To determine whether changes observed in the attitudes and practices of teachers were as a result of professional development initiatives, data was collected before and after the teachers experienced the professional development programme. The data was gathered using six instruments.

1. Pre- and post-intervention teacher questionnaires;
2. Pre- and post-intervention pupil questionnaires;
3. Pre- and post-intervention pupil interviews;
4. Post-intervention teacher interviews;
5. Pre- and post-intervention assessment of teachers' understanding of key science concepts.
6. Monitoring Project Development – survey, evaluation and reflection sheets.

As a particular feature of the project a close up study of three schools was designed to add depth to the findings of the study. The main aim of this was to provide detailed analysis about teachers' and pupils' attitudes to science in their classrooms over the two years of the programme. Data from the close up study schools were gathered from pupils and teachers using questionnaires and group interviews (pre- and post-intervention). The instruments and procedures that were used for the study as a whole are described below.

6.5.1 Questionnaires

The questionnaires used in this study contained closed and open questions, allowing for a more complete picture to be produced. The closed questions needed a specific response, participants decided on an answer that applied to them from a given range of alternatives. The open questions gave the participants more autonomy when answering the survey questions and required them to create their own answers.

Pilot Study

The pupil questionnaire was piloted thoroughly in two small rural primary schools, with pupils from 4th to 6th class i.e. similar backgrounds to the target participants for this study. The teacher questionnaire was piloted with teachers from a variety of primary schools (rural, urban, small and large). Participating teachers were encouraged to give frank comments and sharp criticism. The pilot study was beneficial in that it enabled the researcher to recognise problems with data transfer, time required to complete the questionnaire, and to correct possible ambiguities in the phrasing of questions. Using the feedback from the pupils and teachers, several questionnaire items were revised. The pilot study participants signified that it took the teachers an average of 15 minutes to complete the questionnaire, and pupils an average of 25 minutes. After piloting, the questionnaires were reviewed by two experts who suggested additional minor revisions.

The pre-intervention pupil questionnaires (appendix C, p. 257) were administered to 281 pupils (from 4th, 5th and 6th class) in October 2008, prior to use of the intervention programme in the classroom. The pupils were informed of the purpose of the study. They were asked to respond to each question by placing an X over the response which best described their reaction to that question. Although they were urged not to respond to any questions they did not understand, they were encouraged to ask the meaning of questions or words they did not comprehend. The post-instruction pupil questionnaires were administered to 6th class pupils in June 2009 (as they were leaving the school to go to secondary school in September 2009) and to 5th and 4th class pupils in June 2010.

Teacher questionnaire (pre/post intervention)

The measurement scales for the main parts of this questionnaire were adapted from Pell and Jarvis (2003) and consisted of a five-point Likert type scale for each subject. The questionnaire was broken up into 2 main parts in order to obtain various types of information.

- Part one asked teachers to provide personal information which could have some influence on their attitudes towards science, including, gender, teaching experience, qualification in science (pre-service and in-service), and size of school.
- The second part of the questionnaire was designed to gather information relating to teacher confidence; teaching science as well as other subject areas of the primary curriculum, and teaching different aspects of the primary science curriculum. It measured their confidence in teaching science content, developing children's scientific and design-and-make skills, and teacher attitudes towards different approaches to science teaching.

The post-intervention questionnaire sought to identify changes in teacher confidence, and approaches to teaching and learning science. It attempted to make an assessment of the kinds of changes that had taken place and the extent and significance of these changes.

Pupil questionnaire (pre/post intervention)

The design of the pupil questionnaire closely mirrored the questionnaire used by Varley et al. (2008) in their research into "pupils" attitudes to science. The reason for using a similar questionnaire was to make as valid a comparison as possible with their findings. Both questionnaires used a three-point Likert scale "smiley" face to help the children to show the strength of agreement with a statement. The questionnaire in this study is divided into six parts:

- Pupils' attitudes to school;
- Pupils' attitudes to learning about science topics found on the primary science curriculum;
- Pupils' attitudes to science experiments in school;
- Pupils' attitudes to learning in science;

- Pupils’ attitudes to science itself.

In the final part, pupils were asked to respond to a number of open-ended questions regarding their favourite science lesson and least favourite lesson. They were also asked to “draw a picture of yourself and your class doing science at school”. The post - intervention questionnaire sought to identify changes (positive or negative) in pupils’ attitudes under these same headings and tried to establish some of the factors that might have influenced pupils’ readiness or ability to change.

There is wide support for drawings as a means of collecting information from children and recording expressions and experiences (Barraza 1999; Mac Phail and Kinchin, 2004; Selwyn et al., 2009). Barraza (1999, p. 49) argues that drawings allow children to easily express their emotions and attitudes. He states:

> Use of drawings for evaluation purposes is a powerful tool, since most children tend to enjoy drawing without any sign of tension... drawing avoids linguistic barriers....provides a ‘window’ into their thoughts and feelings.

Selwyn et al. (2009) claim the use of drawings is an appropriate means of allowing children to express themselves within a research process (p. 912). Mac Phail and Kinchin (2004) maintain drawings can be seen as an innately child-centred process, with the non verbal nature of drawings freeing the children to express emotions and attitudes that would be otherwise difficult to assess. They also point out a key weakness of using drawings as a form of data generation, being that the data collected through drawings are constricted by the skill of the artist, and can only reflect the values that can be represented graphically (p. 89). Mac Phail and Kinchin stress “there is support for viewing drawings as “group data”, expressing a group’s cultural pattern rather than viewing drawings as conveying attitudes of the individual”. Accordingly, the focus of attention of the present study was on recording patterns across the drawings rather than trying to draw conclusions about the individual children based on their drawings.

Data Analysis

Data (Likert scales) from both questionnaires were coded and inputted into SPSS (Statistical Package for the Social Sciences) version 15. Using the comparative method of developing categories (Glaser & Strauss, 1967) see section 6.9, the open question responses and drawings (pupil questionnaire only) were analysed by the researcher and a colleague.

6.5.2 Interviews

Semi-structured interviews were used in this study for both teachers and pupils. These allowed the researcher to ask the participants a number of structured questions based on the questionnaire and to branch off at times and explore their responses in more depth. Most importantly, it provided the participants with the opportunity to answer the questions and expand upon these answers by giving more information than may have been requested. Semi-structured interviews also allowed the researcher to change the order of questions, based on his view of what appeared most suitable in the context of the interview.

Teacher interviews

Three separate group interviews with teachers (one for each cluster) took place in June 2010; no interviews were conducted prior to the intervention programme. Each interview lasted between 20 - 30 minutes and was audio recorded. The interviews took place at the end of the final workshop. The interview protocol consisted primarily of open-ended questions (appendix D, p. 263) that involved in-depth probing of teachers' perceptions of the intervention programme and its impact on their teaching beliefs and teaching practice. Examples of questions include: Did the programme benefit you and/or your pupils? What aspect of the programme had the greatest benefit for you and/or your pupils? Participants were told in advance that the interviews would be audio recorded for transcription purposes.

Pupil interviews

Three separate group interviews with pupils (one for each cluster) took place prior to the intervention programme in October 2008. However, because of circumstances outside the researcher's control one of these interviews (Thomson school) took place a week after the first intervention workshop had occurred. In June 2010 (post-intervention) the same three separate groups were re-interviewed. Three schools (one from each cluster) were randomly selected. Within these schools teachers were asked to randomly select six pupils for interview; three males and three females with varying academic abilities and attitudes towards science. Each interview lasted between 20 - 35 minutes and was audio recorded.

The pre-intervention interviews consisted of several broad open-ended questions, aimed at establishing pupils' attitudes to being at school, their experiences of learning science at school and their views of science in general (appendix E, p. 264). The post-intervention interviews sought to identify changes in pupils' attitudes under the same headings, and tried to establish some of the factors that might have influenced pupils' change of attitude. The researcher chose to carry out group interviews involving six pupils per interview (three interviews pre-intervention and three post-intervention) because he felt that a group dynamic would allow him to gain more insights into the pupils' experiences of school science, something that might be less likely to be achieved through individual interviews.

Data analysis

The information gathered from the interviews helped to complement the data acquired from the questionnaires. The interviews were audio-taped and transcribed. The transcripts were put into a word document. Interviews were held in a private room at the pupil's school. A number of interview questions were adapted from the pupil interview used by Varley et al. (2008) so a comparison could be conducted between both studies at a later date.

6.5.3 Teacher understanding of science concepts

The research discussed in Chapter Four (section 4.3) revealed that even when teachers have some familiarity with important science concepts, some of their ideas and views are in conflict with scientific views. Many of the teachers' misconceptions are comparable to those of children.

Participating teachers were given a science cognitive test (see appendix F, p. 266) prior to the intervention programme (September 2008) and post-intervention (June 2010). This was to find out their ideas about key science concepts found in the primary science curriculum and to discover whether or not they held misconceptions, regarding key science concepts. Questions used were adapted from Matthews and McKenna's (1996) study of pre-service primary teachers' understanding of basic science concepts and were written to ensure compatibility with the requirements of the primary science curriculum. Because of the multi-grade nature of the schools involved in this study no standard measure of science subject matter was taken from the pupils who participated.

6.5.4 Monitoring project development

In addition to carrying out pre/post intervention questionnaires and interviews, there was provision for building in new features during the actual implementation of the research. At the start of the intervention programme the researcher visited the participants in all 15 schools. The key purpose of these visits included:

- Meeting the participants and pupils in their classrooms – enabling the researcher to see the “real life” classroom environment;
- Carrying out an inventory with the participants with regard to the science equipment they possessed and equipment they would need as the project progressed, see appendix L p. 277 (Irish American Partnership gave each school a small budget to purchase science equipment);
- Carrying out a needs analysis survey with the participants with regard to the professional help they required to enhance the teaching and learning of science in their school (appendix G, p. 268). This was also repeated at the start of Year Two.

As discussed in Chapter Five (section 5.2) one of the key characteristics of effective professional development is involvement of participants in the design of their own professional development. These initial school visits gave the participants an active input into the programme design i.e. involvement in picking science content that was relevant to their day-to-day needs. The visits also gave the researcher an insight into the needs of the various participants and enabled him to shape the programme design around those needs. The researcher visited the participants in their schools throughout the duration of the programme, offering encouragement and advice regarding the enhancement of teaching and learning science in their classrooms. He sought to accommodate their particular needs regarding the teaching and learning of science and tried to incorporate these into the content of the workshops. To investigate the benefits, challenges, and impact of the programme on their classroom practice and their pupils learning, teachers were asked to complete an open-ended question survey at end of Year One (appendix H, p. 269). The researcher also analysed teachers’ written evaluations after each workshop (appendix A, p. 248).

6.6 The intervention model

This section draws upon a number of underlying principles of the programme and explains how these were translated into practice in the programmes' design and implementation. The Western Seaboard Science Project (WSSP) professional development programme developed for this study, differed in significant ways from the more traditional approaches previously used in the Irish educational system. As stated in Chapter Five (section 5.2) traditional approaches to professional development, as understood in the Irish context, tend to refer to the one-off or short modular courses provided centrally by the Department of Education and Skills. The WSSP programme, in contrast, provides an alternative to current practice. Many of the key features of the WSSP programme are derived from the *Teaching and Learning for the 21st Century* (TL21) professional learning model, (see section 6.7 below) that proved successful in effecting promising developments in professional attitudes and practices among Irish post-primary teachers in a recent CPD project (Hogan et al., 2007). The present study has also drawn together elements of the research literature on teacher professional development, key themes emerging from the relevant literature (discussed in Chapters Four and Five) provided guidance. Defining features of the WSSP programme included an emphasis on:

Active participation – from the start the programme workshops were of an interactive nature, with lecture-style presentations being kept to a minimum. Workshops were designed and convened by the researcher, in on-going consultation with the participants. As mutual trust and openness grew among participants, participants themselves were encouraged to take a more active and responsible role in the design of the workshops. The programme, while facilitated by the researcher, was mainly in the hands of the participants.

Meaningful Collaboration – an important feature of the programme was to build up trust between the teachers as a group, and the researcher, participants were encouraged to share their expertise and views on teaching and learning processes centred on their experiences. This was encouraged and facilitated using a variety of strategies such as: sharing resources and ideas; discussing pedagogic practice, and access to a password protected virtual learning environment; "Moodle".

Continuity – The programme was planned as organised events within a progressive sequence (over 2 years) as distinct from being short courses or "once-off" events carried out at intermittent intervals. Each workshop had specific contributions to make to the gradual development of particular capacities on the part of the participants.

Feedback – From the outset of the programme the researcher was aware that very often the long term impact of professional development programmes (in the Irish context) on the teacher's own classroom experience and the pupils' learning, are all too rarely assessed. Very often it consists of self-reports by teachers of their immediate experience of the workshop itself. Thus, the programme included: (a) feedback from the participants to the researcher after each workshop (b) feedback by participants to workshop colleagues during the workshop and between workshops, regarding teaching and learning initiatives being carried out by them in their own schools, and (c) feedback (evaluation) to the researcher mid-way through the programme and at the end of programme.

6.6.1 WSSP workshops

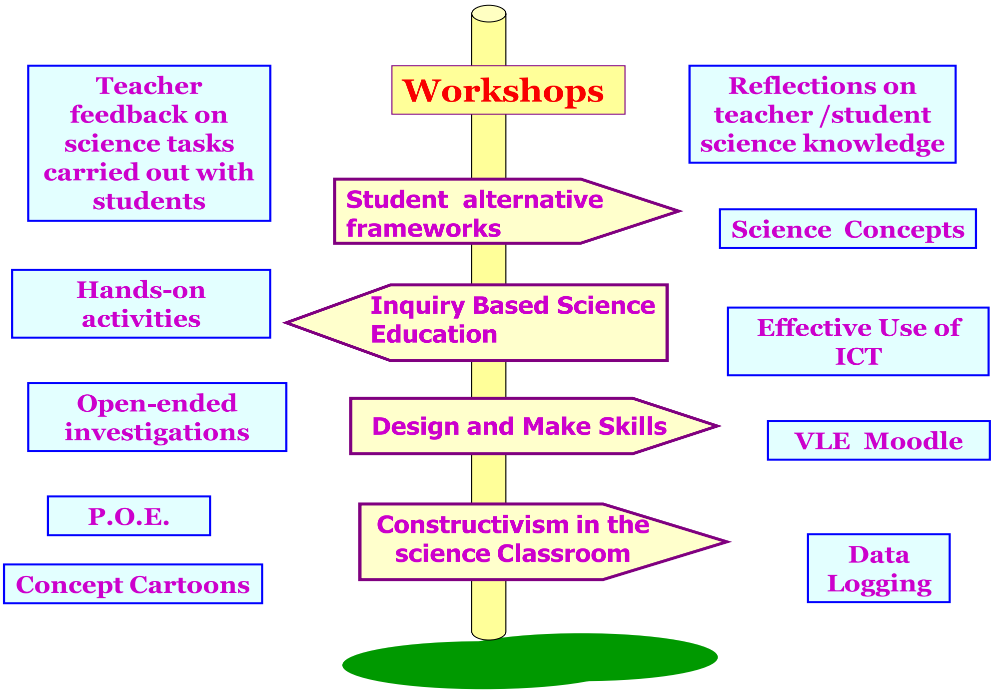
The Western Seaboard Science Project consisted of eleven 3 hour workshops held in and out of school time over a two-year period (October 2008 to June 2010). The workshops were planned and arranged by the researcher, in on-going discussion with the teachers. The researcher also provided on-going support for teachers in between workshops. This support was in the form of a virtual learning environment (Moodle), e-mails, telephone conversations and visits to individual teachers in their schools (when requested). During these visits the researcher demonstrated activities to pupils while teachers observed, and then observed teachers as they introduced workshop activities to their pupils. As the project progressed the researcher acted as a "Critical Friend" to the participants, encouraging them to engage in professional pedagogical dialogue and critically review their own classroom practice. Costa and Kallick (1993) define the role of the critical friend as: "a trusted person who asks provocative questions, providing data to be examined through another lens, and offers critique of a person's work as a friend" (p. 50).

Workshop content varied from workshop to workshop (see figure 6.1 below) in response to teachers' stated needs, and included some or all of the following elements:

- Teacher engagement in a number of hands-on science activities;

- Teachers reflecting on their own science knowledge, in the context of children's ideas;
- Introduction of innovative teaching methodologies;
- Teacher feedback to researcher and participants on science tasks carried out with their pupils in between workshops;
- Teacher discussions related to their experience of teaching science;
- Use of ICT in the classroom and introduction to Virtual Learning Environments – Moodle.

Figure 6.1: Sample of workshop activities



In between workshops teachers were encouraged (not obliged) to carry out action research in their classroom, and document and discuss their findings with colleagues at the next workshop (encouraging teachers to become more reflective of their pedagogic practice). The action research projects were purposefully coupled to the different themes investigated at the workshops.

Principles underlying the workshop approach are listed as follows:

1. The learner constructs meaning and deep understanding through experience. Research by Radford (1998) points to pupils learning best when they are actively engaged in their own learning. The WSSP programme allowed teachers to experience the same content, methods and activities that their pupils were

expected to learn in schools. There were two basic assumptions to this principle: (1) By experiencing the procedures for themselves, teachers are better prepared to help pupils become active, engaged learners, and (2) teachers are most likely to accept and implement science concepts and teaching approaches when both their hands and minds are being used in the process (Radford, 1998).

2. New knowledge is built on previous learning and experience. WSSP encouraged teachers to incorporate what they were learning into what they already knew and challenged their previous understanding that was not in agreement with scientific explanations (cognitive conflict). This was carried out in a context that was real, relevant, interesting and considered the capacities of all the participating teachers.

3. WSSP encouraged teachers to promote effective teaching and pupil learning by providing them with a range of knowledge bases – science content, pedagogy, learning theories.

4. Targeting issues that are relevant to the classroom practice of the participants. During the lifetime of the programme, participants were involved in shaping its content and direction "a sense of ownership is a vital element in creating a supportive environment for teachers" (Callan 2006, p.117). From the very beginning, teachers were encouraged to indicate their preferences for workshop topics and the format of the workshops, as well as the number, time and locations of workshops.

6.7 Role of the researcher

The researcher came into this project with a wide experience as a researcher in a number of professional development projects, including the "Teaching and Learning for the 21st Century" Project (Hogan et al., 2007), and the "TL21 Transfer Initiative" (2007 - present). In addition, he had experience of teaching science at primary level and secondary level and teaching science education to pre-service primary and second level teachers. Based on the researcher's knowledge of professional development, science education, and experiences carrying out research, he believed that he was qualified to carry out this research and bring a unique perspective to the interpretations. Traditionally, with quantitative research the researcher assumes a "detached" role, thus making a certain kind of scientific objectivity possible. However, qualitative research by its nature cannot be objective in a scientific sense, as it is not trying to confirm or refute a scientific hypothesis. The researcher has a key role in this study trying to furnish warranted ideas and possibilities for enhancing the capacities and accomplishments of educational practitioners.

The intervention programme used in this research was designed by the researcher. Thus, the researcher's beliefs and values regarding the teaching of science and what constitutes effective professional development (informed by the research literature) were embedded in the research. The researcher's centrality was an important component of the research. However, every attempt was made to ensure objectivity when analysing the data and a number of measures were taken to ensure reliability and validity of the data.

The project was co-funded by the Irish American Partnership (IAP) and the Department of Education and Skills (DES). The funding had two key purposes: (1) the development and delivery of a professional development programme to enhance the teaching and learning of science in the participating schools, and; (2) the provision of a detailed evaluation of the impact of the programme on the quality of teaching and learning of science in Irish primary schools. The present research study forms the research dimension of the project.

The author of the present study shared a dual role as programme coordinator and researcher. To maintain the integrity of the programme, avoid any conflict of interest and reduce anxiety among the participants, the researcher informed the teachers individually (on his initial visits to the schools) of this dual role. He also advised them of his intention to carry out the present study and asked for their voluntary participation in this study as well as the programme. The researcher let them know that they could participate in the WSSP programme without getting involved in the present study. He also explained the purpose and research goals of the present study. The researcher assured the teachers that the data and findings generated from the study would not be used for performance evaluations of their pupils or themselves. He also disclosed to them that one of the main goals of the present study was to inform educational practitioners (such as policy makers and support agencies) of the impact of the programme on teacher professional development. With this information all of the teachers (in the 10 schools) agreed to participate in both the programme and this research study.

6.8 Triangulation and reliability of data

An important advantage of a mixed methods approach is that it permits a greater measure of triangulation than would be possible under a single-method approach, a point noted by Robson (2002, p.371), among others. Cohen, Manion and Morrison (2000) argue that triangulation of data allows the researcher to check for inferences drawn from one source of data with data from another source (p. 12). Triangulation also permits the researcher to validate data by using one data collecting method to act as a check on the findings of another. Triangulation was carried out in this study to enhance the validity and creditability of the research. The researcher used various data sources in the study, including questionnaires (closed and open-ended responses), semi-structured group interviews, and informal observations. While multiple methods of data collection do not verify that the researcher is correct, they can provide consistency and are not dependent on one position which Denscombe (2007) argues, enhances validity.

6.9 Inter-rater reliability

Using the constant comparative method for developing categories (Glaser & Strauss, 1967), the researcher and a colleague categorised and analysed the open-ended questions and pictures acquired from the pupil questionnaires. Categories emerging were coded, discussed and recoded until no further new categories emerged from the data (Varley et al., 2008). When this was achieved, an inter-rater reliability was carried out with a 10% sample of the questionnaires. To achieve this, the number of times each response was allocated to a specific category by the two raters was divided by the total number of ratings. This provided a percentage of the agreement that existed between the ratings given by both raters, hereby, increasing the trustworthiness of the data analysis.

6. 10 Ethical considerations

Ethical considerations permeate the research design of this study. The researcher took the following steps to ensure that the research met appropriate ethical safeguards:

- Participation of schools and teachers in this research was on a voluntary basis, participants were able to withdraw from the study at any time (participating teachers were encouraged to sign up for the duration of the project);
- All schools and participants were notified in writing (appendix I, p. 271) of the nature and purpose of the research - the method of data collection, the extent of their involvement and the confidentiality and anonymity of the material;

- Written permission to proceed with the study was obtained from all participating teachers;
- Parents and/or guardians of pupils involved in the research were informed about the research purposes and procedures and were given the opportunity to withdraw their children from aspects of the research if they so wished;
- Written consent (appendix J, p. 272) was sought from parents and/or guardians of the pupils to audio record children in the classroom;
- All participants were notified that all interviews were to be recorded;
- Great care was taken to ensure anonymity. The researcher was the only person to see any identifying information (name of participant or school) – in the case of qualitative data from interviews. The participants were notified that although the information they were providing might be used directly in the study, their identity would be coded;
- Accurate transcripts and written interpretations and reports were available to participants;
- The participants were informed of all data collection devices and activities.

In summary, the researcher made every attempt to treat the participants of this study with the utmost respect, dignity and anonymity.

6.11 Summary

The design of this research project employed a mixed method approach, which uses both quantitative and qualitative methods in the context of an action research methodology. The quantitative method used pre- and post-intervention questionnaires of teachers and pupils. The quantitative questionnaires were conducted with a large sample size of pupils (n=281) and all the teachers participating in the study (n=24) to provide quantifiable reliable data that could be generalizable to a larger population. The qualitative method used included semi-structured interviews with teachers and pupils, open-ended questions from the pupils' questionnaire and teacher reflection and evaluation templates. These were used to obtain a more in-depth analysis and investigate new research themes that might develop as the project progressed. An action research approach was deemed most appropriate to account for the researcher's role as a practitioner in developing the professional learning intervention and acting as the facilitator. This chapter has also provided an in-depth explanation of the data collection strategies. The next three chapters will address the results of the study. In Chapter Seven quantitative and qualitative data related to the findings from teacher questionnaires, interviews, reflection templates and cognitive tests are presented and analysed.

Chapter 7

Presentation and Analysis of Research Data (Part 1)

Findings from Teachers

Introduction

Owing to the extensive amount of data collected from questionnaires, teacher cognitive tests and semi-structured interviews with teachers and pupils, the presentation and analysis of data for the study has been divided into three chapters. In this chapter, findings from teachers are presented and analysed. These findings include data from questionnaires (pre- and post-intervention) interviews and cognitive tests. The questionnaires and cognitive tests were administered in September 2008 and again in June 2010. The interviews took place in June 2010 (see Chapter Six, section 6.5.2). Chapter Eight will be concerned with the presentation and analysis of all pupils' (from fifteen schools) responses to pre- and post-intervention questionnaires. Chapter Nine will explore in more detail, the responses from pupils and teachers from three selected schools to pre- and post-intervention questionnaires and interviews.

The findings from this chapter are concerned with the first aim of the study: investigating the extent to which the WSSP professional development model can actively promote improvements in confidence, competence, attitudes and levels of knowledge among primary teachers, where the teaching of science is concerned. The following research questions are addressed in this section of the study:

- What changes in teachers' confidence in teaching science and competence in their knowledge of the science curriculum occurred during the study?
- What changes in teachers' attitudes to teaching science occurred during the study?
- What changes in teachers' classroom practice occurred during the study?
- What aspects of the intervention programme promoted or inhibited teachers' subject confidence, competence and attitudes?

This chapter is divided into five main parts. The first part (section 7.1) begins with the presentation and analysis of the data collected from the pre/post intervention questionnaires with the participating teachers, under nine main headings. The second part (section 7.2) focuses on data obtained from the semi-structured group interviews with teachers; the main issues relating to these interviews are presented and analysed. This is followed by the third part (section 7.3) which presents and analyses data from topics for future workshop templates and teachers' reflection monitoring templates. Part four (section 7.4) analyses the data collected from the teacher science cognitive tests (pre/post) as outlined in section 6.5.3, the purpose of which was to investigate the teachers' understanding of various science concepts found in the primary science curriculum. The chapter concludes with a discussion (section 7.5) of the more salient issues that have emerged in the course of the analysis.

7.1 Questionnaire (pre / post intervention)

The responses to the closed questions on the teacher questionnaire were analysed statistically using SPSS version 15. Parametric tests were carried out, including t-tests and correlation analysis. Reliability analysis of all grouped Likert items was carried out calculating Cronbach's alpha coefficient. This yielded values of 0.7 or higher, this was deemed reliable for attitudinal responses (Cohen, Manion & Morrison, 2000, p. 506).

7.1.1 Personal information

The first section of the questionnaire provided a profile of the teachers who participated in the programme. The number of male teachers to female teachers was reasonably proportionate, especially considering that primary teaching in Ireland is a female dominated profession. Seven males and seventeen females participated in the study. The teaching experience of the participants ranged from less than 5 years to 20 years and over. It can be seen from table 7.1 that there was a heavier representation of teachers who had been teaching for over 20 years, approximately 55%. In fact over 88% of the teachers surveyed had a teaching experience of 6 years or more.

Table 7.1: Personal characteristics of participating teachers (n = 24)

	Frequency	Percentage
Gender		
Male	07	29
Female	17	71
Teaching Experience		
0 – 5 years	03	12
6 – 10 years	05	21
11 – 15 years	02	08
16 – 20 years	01	04
Over 20 years	13	55
Highest Qualification in Science		
Junior/Inter Certificate	04	21
Leaving Certificate	17	67
Degree	01	04
None	02	08
Science Subjects studied for Leaving Certificate		
Physics	02	08
Chemistry	04	16
Biology	16	67
Physics/Chemistry	01	04
Science Professional Development Courses attended		
Diploma	01	04
Curriculum implementation in-service days	18	75
Discover Science	02	08
Summer Course in Teaching College	03	12
Other	03	12
None	04	16

The science qualification of the participants varied; for the majority of participants (67%) the Leaving Certificate was their highest qualification in science. Only one of the participating teachers (4%) completed a Bachelor of Science degree prior to gaining a position on a Post Graduate course in teacher education. All the participants studied prescribed courses in science as part of their initial teacher education, 12 % studied the new primary science curriculum (1999). The remainder, 88% studied science for the 1971 revised primary curriculum. Four teachers (16%) had only Junior/Intermediate Certificate science and two (8%) had no science background at all. A considerably higher percentage (67%) of the respondents took biology to Leaving Certificate than any of the other science subjects i.e. sixteen respondents. A low percentage of teachers studied the physical sciences: two (8%) studied physics, four (16%) studied chemistry and one (4%) studied physics/chemistry. All primary teachers are obliged to teach the science curriculum, which encompasses aspects of physics, chemistry and biology. A concern is that the teachers' science background seems to be largely focused on the biological as opposed to the physical sciences i.e. 67% of them have biology to Leaving Certificate and 84% and 92% respectively, do not have chemistry or physics at Leaving Certificate level.

The teachers were also asked to specify science professional development courses they attended prior to this study. The majority of respondents (75%) attended the curriculum implementation in-service days in 2003 provided by the Department of Education and Science. Responses to this section of the questionnaire demonstrated a distinct lack of participants attending science professional courses beyond DES in-service days. Only two participants (8%) had attended workshops provided by Discover Primary Science Ireland and four (16%) had taken an in-service science summer course, offered in a number of education colleges. One teacher had pursued an accredited path, achieving a Diploma in Science Education. Four teachers (16%) had not attended any science professional development courses.

7.1.2 Teacher confidence across seven subject areas

The first section of the questionnaire asked teachers to rate their confidence, on a five point Likert scale, in teaching English, Irish, history, mathematics, geography, science and information technology (ICT). A score of 1 indicates very low confidence ("I require help with this"), a score of 2 indicates low confidence, a score of 3 indicates average confidence, a score of 4 indicates high confidence and a score of 5 indicates very high confidence ("I have no problem with this"). Table 7.2 shows the mean rating score for confidence in each of these subjects' pre-intervention and post-intervention. In table 7.2 and subsequent tables in section 7.1, parametric paired t-tests are used to investigate statistically significant changes between pre-tests and post-tests.

Table 7.2: Changes in teachers' confidence across seven subject areas (pre- and post- intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
Subject	Mean	Standard Deviation	Mean	Standard Deviation	Sig
English	4.50	0.598	4.55	0.510	0.665
Irish	4.23	0.813	4.32	0.646	0.427
History	4.41	0.734	4.50	0.512	0.427
Geography	4.41	0.734	4.50	0.598	0.492
Mathematics	4.41	0.590	4.45	0.596	0.665
Science	3.23	0.869	4.05**	0.486	0.000
ICT	3.41	0.959	3.73	0.703	0.016

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, teachers were far less confident teaching both science and ICT, than teaching English, Irish, history, mathematics and geography. The pre-intervention findings are similar to the results found by Harlen et al. (1995) and the pre-intervention findings of Jarvis and Pell (2004). In 1995, Harlen and colleagues working with teachers in Scottish primary schools reported that teachers were less confident teaching science, than most other subjects on the curriculum. When asked to rate their confidence in teaching eleven subjects found on the primary curriculum, science was in eighth place. Jarvis and Pell (2004), working with primary teachers in English schools, found that teachers were less confident in teaching science (even though it was a core subject), than teaching English or mathematics.

The post-intervention findings show that there was a statistically significant increase ($p < .01$) in teachers' confidence in teaching science (from a mean of 3.23 to a mean of 4.05). This finding shows that teachers' confidence in teaching science moved from an average level of confidence to a high level of confidence i.e. from a level where teachers are capable of teaching science, to a substantively more self-assured level. It also shows that teachers' confidence in teaching science, no longer differed greatly from their confidence in the teaching of other subjects. This is an important finding, showing clearly that advances of considerable magnitude in teachers' confidence in teaching science were made and that these advances were attributable to the intervention programme. This concurs with research carried out by Jarvis and Pell

(2004). Their research investigated the effects of a two year professional development programme on 70 primary teachers' confidence, attitudes and understanding of science. They found at post-intervention, teachers rated their confidence to teach science increased significantly and no longer differed from their confidence teaching English.

7.1.3 Teacher confidence in teaching the content of science curriculum

The content of the primary science curriculum is divided into four strands: living things, energy and forces, materials and environmental awareness and care (DES, 1999a). All primary teachers are expected to cover all four strands regardless of their level of interest or qualification in science. This section of the questionnaire asked teachers to rate their confidence teaching the four different strands of the curriculum on a five point Likert scale. A score of 1 indicates very low confidence ("I require help with this"), a score of 2 indicates low confidence, a score of 3 indicates average confidence, a score of 4 indicates high confidence and a score of 5 indicates very high confidence ("I have no problem with this"). The participating teachers were asked a total of twenty questions based on the four different content strands of the science curriculum – four questions concerned with living things, twelve concerned with energy and forces, two concerned with materials and two concerned with environmental awareness and care.

Table 7.3 shows the mean rating score for teachers' perceived confidence in teaching each of the selected content areas pre-intervention and post-intervention. Pre-intervention, teachers had high mean scores (average to high confidence level) regarding teaching about living things and environmental awareness, and they were reasonably confident (average confidence level) teaching about materials. However, they had low to average levels of confidence teaching about energy and forces. In general, teachers' perceived confidence in physical science items was lower than in biological science items. Teachers had difficulty with a number of the more conceptually difficult physical science topics, including: how sound travels, how sound is produced, the splitting of light, mixing colours, how we see things, the force of gravity, and electrical energy. These results are consistent with the findings of Harlen et al. (1995), Murphy et al. (2007) and the pre-intervention findings of Jarvis and Pell (2004).

Table 7.3: Teachers' perceived confidence in teaching content of Primary Science Curriculum (pre- and post-intervention)

	Pre Intervention (N = 24)		Post Intervention (N=22)		
Content	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Living Things					
Structure of some of the body's major internal and external organs	3.91	1.005	4.23	0.869	0.031
Reproductive systems of both males and females and physical changes in both	3.45	1.011	3.73	0.883	0.030
Some of the factors that affect plant growth	3.77	0.922	4.00	0.873	0.021
Some of the ways plants reproduce	3.64	1.002	4.05	0.722	0.016
Energy and Forces					
The refraction of light using mirrors	3.00	0.976	3.55**	0.671	0.004
The splitting and mixing of light	2.86	1.037	3.55**	0.912	0.001
How sound travels through materials	3.05	1.133	3.91**	0.684	0.000
How sound is produced	3.14	0.990	4.09**	0.750	0.000
Sources of heat	3.41	0.959	3.95**	0.844	0.002
Transfer of heat (conduction, convection and radiation)	3.23	1.006	3.95**	0.899	0.000
Electrical current and construction of simple circuits, (e.g. lamps, buzzers, motors)	3.05	1.495	4.00**	0.976	0.001
Electrical energy	3.00	1.234	3.91**	0.811	0.000
Magnets and their push and pull effects	3.77	1.193	4.09	0.868	0.069
The making of magnets	2.86	1.082	3.64**	0.953	0.002
The effect of friction on movement	3.27	1.120	4.05**	0.785	0.000
The force of gravity	3.09	0.921	4.00**	0.756	0.000
Materials					
The effects of heating and cooling on a range of solids, liquids and gases	3.23	0.869	3.68**	0.780	0.002
How a wide range of materials may be changed by mixing	3.18	1.006	3.50	0.913	0.090
Environment					
The effects of human activity on the environment	4.09	0.921	4.41	0.666	0.069
The need to conserve resources	4.14	0.889	4.45	0.596	0.069

** $p < .01$ significant difference paired *t*-test.

Post-intervention, there was a statistically significant improvement ($p < .01$) in teacher confidence in twelve of the twenty questions asked. All twelve questions were concerned with the physical science content of the curriculum (energy and forces and materials). Teachers became much more confident with a number of the more conceptually challenging physical science topics, such as those mentioned previously. For example, for topics such as "how sound is produced", "the force of gravity" and "the effect of friction on movement" teachers confidence levels moved from an average level to a high level of confidence. This is an important finding, again showing that advances of considerable magnitude in teachers' confidence in teaching challenging physical science topics were made, and that these advances were attributable to the intervention programme.

Table 7.4 shows the mean rating score for changes in teachers' confidence in teaching across the four strands of the science curriculum. Likert items from each content strand were grouped together. Reliability analysis of all grouped Likert items was carried out calculating Cronbach's alpha coefficient. This yielded values of 0.7 or higher, this was deemed reliable for attitudinal responses (Cohen, Manion & Morrison, 2000, p. 506)

Table 7.4 Changes in teachers' perceived confidence across the four strands of the science curriculum (pre- and post-instruction)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
Science content	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Living things	3.69	0.805	3.89	0.544	0.047
Forces and energy	3.14	0.836	3.89**	0.524	0.000
Materials	3.22	0.839	3.59**	0.811	0.009
Environment	4.11	0.899	4.43	0.623	0.069

** $p < .01$ significant difference paired *t*-test.

At the pre-intervention stage, teachers were very confident about teaching living things and environmental awareness and less confident about teaching energy and forces and materials. Post-intervention there was a statistically significant positive change ($p<.01$) in teachers' perceived confidence in teaching energy and forces and materials. However, there was no statistically significant change in their confidence in teaching living things and environmental awareness. This result is very significant, the WSSP programme placed a strong emphasis on physical science topics, especially those perceived as difficult by the participants, and it highlights the need for professional development courses for primary teachers to prioritize areas of content that are challenging to the participants.

7.1.4 Teacher confidence in developing pupil scientific and design-and-make skills

The primary science curriculum is divided into two distinct sections: a content strand and a skills section (DES, 1999a). Teachers are expected to help pupils to develop their scientific and design-and-make skills. This section of the questionnaire asked teachers to rate their confidence (on a five point Likert scale) in their own capacity in developing pupils' scientific and design-and-make skills. A score of 1 indicates very low confidence ("I require help with this"), a score of 2 indicates low confidence, a score of 3 indicates average confidence, a score of 4 indicates high confidence and a score of 5 indicates very high confidence ("I have no problem with this"). Table 7.5 shows the mean rating score for teacher confidence in their capacity to develop both sets of skills, pre-intervention and post-intervention.

Table 7.5: Teachers' confidence in their own capacity to develop pupils' scientific and design-and-make skills (pre- and post-intervention)

	Pre Intervention (N =24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Pupil scientific skills					
Identify relevant question to investigate	3.05	0.999	3.50**	0.673	0.009
Recognise their observation skills	3.25	0.869	3.73**	0.631	0.001
Making and testing hypotheses	2.86	1.037	3.64**	0.790	0.000
Recording and presenting data	2.95	0.844	3.68**	0.780	0.000
Ability to interpret and explain data	3.14	0.911	3.82**	0.588	0.001
Recognise investigation is unfair if relevant variables are not controlled	3.41	1.141	3.91**	0.921	0.002
Ability to address how science might affect their lives	3.50	1.102	4.00**	0.873	0.001
Pupil design-and-make skills					
Pupils exploring skills	3.36	0.902	3.86**	0.710	0.002
Pupils planning skills	2.82	0.853	3.64**	0.658	0.001
Pupils making skills	3.09	1.065	3.77**	0.752	0.000
Pupils evaluating skills	2.82	1.006	3.45**	0.739	0.000

** $p < .01$ significant difference paired *t*-test.

Pre-intervention teachers' confidence in their capacity to develop pupils' scientific skills and design-and-make skills, generally fell within the mid-range mean score (i.e. low average level of confidence). However, their confidence was low in the teaching or cultivation of the following learning strategies: making and testing hypotheses, recording and presenting data, pupils planning skills, and pupils evaluating skills. This could be due to the fact that these skills might be seen as more science specific and require teachers to have a strong science knowledge background. Post-intervention, there was a statistically significant improvement ($p < .01$) in teacher confidence in developing both sets of skills in all items asked. The results show that teachers' confidence in most items, moved from a low average level of confidence to a high average level of confidence i.e. from a level where teachers are capable of teaching science to a substantively more self-assured level. For three items: "making and testing hypotheses"; "pupils planning skills"; "pupils evaluating skills", teachers' confidence moved from a low level of confidence to a high average level of confidence. These results clearly indicate that the intervention programme had a substantial impact on teachers' confidence in developing the pupils' scientific and design-and-make skills. This is very encouraging, because the researcher incorporated the development of these skills into the workshops throughout the duration of the intervention programme.

7.1.5 Teachers' confidence in their own science teaching skills

This section of the questionnaire, unlike other sections, is not based on items from the teacher guidelines for the primary science curriculum. The questions are based on the science teaching skills that the researcher deems to be important for a teacher to possess, in order to teach science effectively. Teachers were asked how confident they felt deploying these skills in science lessons, using a five point Likert scale. A score of 1 indicates very low confidence ("I require help with this"), a score of 2 indicates low confidence, a score of 3 indicates average confidence, a score of 4 indicates high confidence and a score of 5 indicates very high confidence ("I have no problem with this"). Table 7.6 shows the mean rating score for confidence in teacher's deployment of teaching skills, pre-intervention and post-intervention.

Table 7.6: Teachers' confidence in their own science teaching skills (pre- and post-intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
Skill	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Using questioning as a tool in science teaching	3.77	1.02	4.50**	0.598	0.002
Explaining science concepts to pupils	3.77	0.869	4.14**	0.774	0.002
Encourage children to try out own ideas in investigations	3.09	0.894	3.91**	0.750	0.000
Encourage pupils to think for themselves	3.32	0.796	4.00**	0.617	0.009
Organising and delivering practical work	3.59	0.733	3.73**	0.631	0.001
Deciding science skills to be developed in an activity	3.09	0.610	3.50**	0.598	0.004
Using ICT to enhance teaching and learning science	2.86	0.941	3.05	0.844	0.162
Assessing practical work	3.59	0.854	3.77	0.752	0.162

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, teacher confidence in their own science teaching skills was uncertain (low average confidence level), especially in areas such as: "encouraging children to try out their own ideas in investigations", "encouraging pupils to think for themselves", "deciding what science skills are to be developed in an activity", and "using ICT to enhance teaching and learning science". Post-intervention, there was a statistically significant improvement in teachers' confidence ($p < .01$) in their own science teaching skills in six of the eight questions asked. For three items: " using questioning as a tool in science teaching"; "explaining science concepts to pupils"; "encouraging pupils to think for themselves" teachers' confidence level moved from an average confidence level to a high confidence level – from a level where teachers are capable of teaching science to a substantively more self-assured level. One can conclude from these results that the WSSP programme had a positive influence on developing teachers' own teaching skills – leading to a change in teachers' classroom practice. This is very welcome, because during the workshops the researcher introduced the teachers to innovative teaching approaches and theories of learning and encouraged teachers to incorporate them in their classroom practice.

7.1.6 Teachers' use of innovative teaching methodologies in science

The teacher guidelines for the science curriculum (DES 1999b) recommend that teachers use various teaching approaches to facilitate the effective implementation of the science curriculum: "the effective teacher will use a combination of approaches to meet the needs of the pupils and to suit the objectives of the unit of work" (p.53). Using a five-point Likert scale teachers were asked how often they used innovative teaching methodologies in science lessons. A score of 1 indicates "not at all" a score of 2 indicates "rarely" a score of 3 indicates "sometimes" a score of 4 indicates "frequently" and a score of 5 indicates "very frequently". Table 7.7 shows the mean rating score for confidence in teacher deployment of innovative teaching approaches, pre-intervention and post-intervention.

Table 7.7: How often teachers used innovative teaching methodologies (pre- and post-intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Teacher questions	4.23	0.813	4.68**	0.646	0.009
Co-operative learning	3.59	1.098	4.14	0.774	0.015
Predict-Observe-Explain	3.23	1.343	4.14**	0.889	0.008
Concept Cartoons	1.59	0.734	3.41**	1.098	0.000
Concept Mapping	2.23	1.110	3.18**	0.958	0.001
Discussion in class	4.09	0.921	4.41	0.908	0.016
Using children's ideas to start a topic	3.41	1.008	4.18**	0.795	0.001
Using hands-on science	3.91	0.921	4.18	0.664	0.110
Using ICT	2.64	1.217	3.05**	0.999	0.004
Written feedback	2.14	1.082	2.73	0.935	0.029

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, teachers seldom used innovative teaching methodologies such as concept cartoons, concept maps, written feedback on assessment work, or ICT in their science lessons. Post-intervention, the frequency with which teachers used teaching methodologies such as teacher questions, and strategies such as, Predict-Observe-Explain (POE), concept cartoons, concept mapping, and ICT showed a statistically significant improvement.

Post-intervention, there was a statistically significant improvement ($p < .01$) in six of the ten questions asked. Close inspection of the results show that for the items: “Predict-Observe-Explain”; “using children’s’ ideas to start a topic”, teachers moved from “sometimes” to “frequently” using them in science class. For the items: “concept mapping”; “using ICT” teachers moved from “rarely” to “sometimes” using them in lessons. The most significant finding concerned concept cartoons, it shows a move across two levels i.e. teachers moved from “not at all” to “frequently” – from a mean score of 1.59 to 3.41.

Using a similar scale, teachers were also asked to indicate how useful they found the innovative teaching methodologies using a five-point Likert scale. A score of 1 indicates “not very useful at all” a score of 2 indicates “not useful” a score of 3 indicates “useful” a score of 4 indicates “very useful” and a score of 5 indicates “extremely useful”. Table 7.8 shows the mean rating score for teachers’ use of various teaching methodologies, pre-intervention and post-intervention.

Table 7.8: How useful teachers considered innovative teaching methodologies (pre- and post-intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Teacher questions	4.00	1.069	4.68**	0.568	0.003
Co-operative learning	4.05	0.950	4.32	0.780	0.030
Predict-Observe-Explain	3.18	1.220	4.09**	0.971	0.003
Concept Cartoons	1.86	1.037	3.77**	1.110	0.000
Concept Mapping	2.27	1.007	3.50**	1.058	0.000
Discussion in class	4.09	1.065	4.68	0.568	0.012
Using children’s ideas to start a topic	3.59	1.141	4.32**	0.780	0.003
Using hands-on science	4.18	0.958	4.55**	0.800	0.008
Using ICT	3.05	1.214	3.59	1.008	0.015
Written feedback	2.68	0.945	3.23**	0.813	0.004

** $p < .01$ significant difference paired *t*-test.

At the pre-intervention stage, teachers seldom used various teaching methodologies such as concept maps and concept cartoons. A possible reason for this was that a sizable number of the participating teachers were not familiar with these teaching methodologies prior to participating in the project.

Post-intervention, there was a statistically significant improvement ($p < .01$) in seven of the ten questions asked. Close inspection of the results shows that for the items: “Predict-Observe-Explain”; “using children’s’ ideas to start a topic”, teachers moved from finding them “useful” to “very useful” in science class. For the items: “concept mapping”; “written feedback” teachers moved from “not useful” to “useful” using them in lessons. Again, the most significant finding concerned concept cartoons. It shows a move across two levels i.e. teachers moved from “not useful at all” to “useful” – from a mean score of 1.86 to 3.77. These findings clearly illustrate that the intervention programme provided some new ideas that the teachers found useful, and willingly engaged with, and incorporated into their classroom practices, especially concept cartoons. This is discussed in more detail in section 7.2.

Further statistical analysis was carried out to investigate if there were any significant differences in the patterns of responses from different sub-groups within the total group of teachers who participated. A correlation analysis between teacher confidence in science teaching and gender, teaching experience and qualifications in science, was carried out. Likert items from each content strand were grouped together to form six subscales. Grouped Likert items gave Cronbach values of 0.7 or higher. This was deemed reliable. The findings and analysis from these different sub-groups are dealt with in the pages that follow.

7.1.7 Gender

Table 7.9 compares the mean rating score for confidence between female and male teachers, concerning their perceptions of their own capacities in various aspects of science teaching (pre-intervention and post-intervention).

Table 7.9: Comparison between female and male responses concerning their perceptions of their own capacities in various aspects of science teaching (before and after intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
Females (n=17)					
Developing pupil scientific skills	3.17	0.711	3.69**	0.618	0.000
Developing design-and-make skills	2.82	0.704	3.53**	0.597	0.000
Developing science teaching skills	3.28	0.635	3.69**	0.567	0.000
How often use teaching methods	3.01	0.694	3.79**	0.562	0.000
How useful find teaching methods	3.32	0.621	4.13**	0.620	0.000
Science content					
Living things	3.73	0.729	3.93	0.563	0.054
Forces/energy	3.01	0.924	3.86**	0.593	0.000
Materials	3.35	0.934	3.77	0.842	0.017
Environment awareness and care	4.00	0.756	4.27	0.594	0.104
Males (n=7)					
Developing pupil scientific skills	3.14	1.111	3.67	0.703	0.068
Developing design-and-make skills	3.46	0.994	4.00	0.595	0.052
Developing science teaching skills	3.49	0.458	3.82	0.450	0.012
How often use teaching methods	2.92	0.452	3.54**	0.507	0.003
How useful find teaching methods	3.00	0.584	3.75**	0.520	0.010
Science content					
Living things	3.61	1.009	3.79	0.529	0.441
Forces/energy	3.44	0.548	3.95**	0.363	0.010
Materials	2.93	0.535	3.21	0.636	0.321
Environment awareness and care	4.36	1.18	4.79	0.567	0.356

** $p < .01$ significant difference paired t-test.

Pre-intervention, female and male mean scores for most of the subscales were similar, falling within the mid-range. However, female teachers' confidence was low in two subscales: (a) developing pupil design-and-make skills, and (b) how often they used innovative teaching methodologies. Male teachers were also low in two subscales: (a) how often they used innovative teaching methodologies, and (b) how useful they found the innovative teaching methodologies. Post-intervention, female teachers showed statistically significant improvements ($p<.01$) in all subscales. Male teachers showed statistically significant improvements in two subscales: how often they used various teaching methodologies, and how useful they found these teaching methodologies. Pre-intervention, both female and male teachers had high mean scores (very confident) regarding teaching about living things and environmental awareness, both were reasonably confident teaching about materials. However, female teachers had lower levels of confidence teaching about energy and forces, than their male counterparts. Post-intervention, both males and females showed a statistically significant improvement in the science curriculum content area – energy and forces.

7.1.8 Teaching experience

Teachers were classified in terms of the number of years since graduating as a primary teacher. Teachers were divided into "most experienced" (qualified 10 years or more) and "least experienced" (qualified less than ten years). Table 7.10 compares the mean rating score for confidence between most and least experienced teachers, concerning their perceptions of their own capacities in various aspects of science teaching (pre-intervention and post-intervention).

Table 7.10: Comparison between most and least experienced teachers' responses concerning their perceptions of their own capacities in the various aspects of science teaching (before and after intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
More than 10 years (n=17)					
Developing pupil scientific skills	3.11	0.831	3.66**	0.653	0.000
Developing design-and-make skills	3.06	0.917	3.72**	0.655	0.000
Developing science teaching skills	3.34	0.587	3.71**	0.577	0.000
How often use teaching methods	2.92	0.478	3.69**	0.578	0.000
How useful find teaching methods	3.14	0.572	3.96**	0.670	0.000
Science content					
Living things	3.68	0.833	3.88	0.567	0.074
Forces/energy	3.14	0.735	3.89**	0.514	0.000
Materials	3.09	0.643	3.44	0.748	0.041
Environment awareness and care	4.09	0.939	4.44	0.659	0.111
Less than 10 years (n=7)					
Developing pupil scientific skills	3.34	0.896	3.74	0.669	0.118
Developing design-and-make skills	2.90	0.576	3.55	0.542	0.012
Developing science teaching skills	3.37	0.636	3.80	0.329	0.095
How often use teaching methods	3.18	1.104	3.80	0.467	0.069
How useful find teaching methods	3.47	0.759	4.16	0.300	0.037
Science content					
Living things	3.75	0.791	3.90	0.518	0.468
Forces/energy	3.15	1.228	3.90	0.616	0.079
Materials	3.65	1.318	4.10	0.894	0.121
Environment awareness and care	4.20	0.837	4.20	0.548	0.374

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, the "most experienced" teachers were uncertain of their confidence in developing pupils' design-and-make skills, and how often they used innovative teaching methodologies. The "least experienced" teachers had limited confidence in developing pupils' design-and-make skills. Post-intervention, the "most experienced" teachers made statistically significant improvements in all five subscale items. The "least experienced" teachers also made positive improvements across all five subscales; however, none of the latter were statistically significant improvements. Only the "most experienced" teachers showed a statistically significant improvement in science curriculum content. This could be because only one of the "most experienced" teachers had studied a physical science subject at Leaving Certificate. Whereas, five of the "least experienced" teachers had studied at least one physical science subject at Leaving Certificate. The improvement was in the area of energy and forces.

7.1.9 Qualification in Science

Teachers were classified into two groups in terms of their qualifications in science. Teachers were divided into "most qualified" in science (those who had at least one science subject at Leaving Certificate or higher) and "least qualified" in science (those that had no science at second level or only had science up to Junior Certificate or equivalent). As mentioned in section 7.1.1 all the participants had studied some science courses as part of their pre-service education. However this was not included in "qualification in science" section for the following reasons: time provided for trainee teachers to study primary curriculum science (1999a) varies from college to college. For example St. Patricks College allocates 44 hours to curriculum science over a three year period. On the other hand, Mary Immaculate College only allocates 12 hours over the same time period (Varley et al. 2008). For those participants who studied science to prepare them for the 1971 revised primary curriculum, the type of science they studied and time given to these studies, varied from college to college. Table 7.11 compares the mean rating score for confidence between teachers "most qualified" and "least qualified" in science, concerning their perceptions of their own capacities in various aspects of science teaching (pre-intervention and post-intervention).

Table 7.11: Comparison between the responses of the "most" and "least" qualified teachers in science concerning their perceptions of their own capacities in the various aspects of science teaching (before and after intervention)

	Pre Intervention (N = 24)		Post Intervention (N = 22)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig (2 tail)**
Most qualified in science (n=17)					
Developing pupil scientific skills	3.25	0.750	3.69**	0.548	0.003
Developing design-and-make skills	3.03	0.851	3.67**	0.583	0.000
Developing science teaching skills	3.46	0.425	3.76**	0.448	0.000
How often use teaching methods	3.09	0.520	3.69**	0.542	0.000
How useful find teaching methods	3.29	0.546	4.05**	0.650	0.000
Science content					
Living things	3.83	0.773	4.02	0.423	0.138
Forces/energy	3.43	0.603	4.03**	0.483	0.000
Materials	3.48	0.782	3.91	0.688	0.013
Environment awareness and care	4.16	0.851	4.47	0.562	0.173
Least qualified in science (n=6)					
Developing pupil scientific skills	2.93	1.057	3.67**	0.874	0.006
Developing design-and-make skills	3.00	0.894	3.71**	0.781	0.010
Developing science teaching skills	3.02	0.845	3.64**	0.738	0.003
How often use teaching methods	2.69	0.806	3.78**	0.605	0.001
How useful find teaching methods	3.02	0.793	3.89**	0.497	0.004
Science content					
Living things	3.33	0.847	3.54	0.714	0.141
Forces/energy	2.39	0.942	3.53**	0.485	0.007
Materials	2.50	0.524	2.75	0.418	0.426
Environment awareness and care	4.00	1.095	4.33	0.816	0.175

** $p < .01$ significant difference paired *t*-test.

Table 7.11 shows that prior to intervention, the mean scores for most of the subscales were similar for the respondents who were "most qualified" in science and those who were "least qualified" falling within mid-range. However, close examination of mean scores show that "least qualified" in science teachers had lower confidence than the "most qualified" in science in all five subscales, especially: developing pupils scientific skills, and teaching physical science concepts forces/energy and materials. Post-intervention, both sets of teachers made statistically significant improvements in all five subscale items. Both also showed statistically significant improvements in science curriculum content. The improvement was in the area of energy and forces.

To summarise, the findings from the teacher questionnaires presented above show that prior to their participation in the intervention programme, teachers were clearly not as confident about teaching science as they were about teaching other subjects. Post-intervention, this difference was no longer discernible. There was an increase in teachers' self-awareness of their capacity to teach the various parts of the primary science curriculum, especially science content, design-and-make skills, and to use innovative teaching approaches that enable pupils to understand science concepts. Findings from the various sub-groups within the total group of participants showed that all sub-groups increased their perceptions of their own capacities in the various aspects of science teaching. These positive changes in teachers' attitudes to school science are clearly attributable to the intervention programme.

7.2 Discussion of results from teacher interviews

Turning now from quantitative to qualitative data, fifteen of the twenty four participating teachers were interviewed. Five were selected from each of the three clusters after the completion of the active phase of the project in June 2010. All twenty four teachers were teaching science in school; however, these teachers were selected because they were teaching the pupils of 4^{th}, 5^{th}, and 6^{th} classes i.e. pupils who participated in the project. The set of questions used to structure the interviews is found in appendix D (p. 263). The interview schedule was divided into two parts. The first part (section 7.2.1) was concerned with determining the impact of the intervention programme on classroom practice. The second part (section 7.2.2) explored teachers' thoughts, opinions and impressions about WSSP as a model of professional development and their experience of professional development to date.

7.2.1 Impact of the intervention programme on teachers' capacities and on classroom practice.

Interview results regarding the impact of WSSP on teachers' classroom practice are based on their responses (see DVD, audio 1, 2, 3) to the following four questions:

- Do you feel more confident teaching science now than before attending the project?

- To what extent has your view of teaching science changed as a result of your involvement in the project?
- To what extent have you introduced new science strategies into your classroom?
- Have you observed any changes in your pupils' attitudes toward science since your participation in this project?

Q1: *Do you feel more confident teaching science now than before participating in the project?*

In response to this question, all fifteen participants interviewed from the three clusters stated that, their confidence in teaching science has improved as a result of their involvement in the project. Teachers across the three cluster groups identified a number of areas that helped to bring about this change including: appreciation of the practical nature of science, understanding of science concepts, and trying different approaches to teaching science.

Practical nature of science

Pre-intervention, the majority of the participants found it difficult to teach the practical aspect of science to their pupils. They were unsure of the nature and process of open-ended investigations. Since their involvement in the project, nine of the fifteen interviewees confirmed that their confidence in handling open-ended investigations had improved. One participant stated "what we do here [workshops] in the hands-on work is very simple, I can ask questions on the activities, this gives me more confidence to go back to my children and try it with them" (Audio 2, 0:22 – 1.12). Another commented:

> when we did open-ended investigations on sound in the workshop... I went back to school set them up with my pupils...I knew exactly what to do... I even knew most of the answers to the questions they asked me; the reason being their questions were more or less the same as the questions I asked when doing the investigation at the workshop... (Audio 2, 3:24 – 3:43)

The researcher was conscious of what Jarvis et al. (2003) had to say about teachers understanding the importance that open investigations can have for their pupils in helping them construct scientific concepts: "in order to construct scientific concepts, children need to be actively involved in articulating and investigating their own questions.... This can often be achieved by linking investigations with conceptual teaching where children are helped to test their different ideas" (p. 40).

Subject Content Knowledge

Four of the fifteen participants (across the three cluster groups) felt that the intervention programme enhanced their understanding of key science concepts found in the primary science curriculum. Comments included: "I have picked up a lot of science at these workshops, theory and practice. I am now more confident, I know what is happening in the science lessons". A teacher in one of the cluster groups spoke of her low confidence in understanding certain science concepts prior to the project: "when I started the workshops my science knowledge was at a very low ebb, it has really improved and I put this down to the discussions, hands-on activities and my enjoyment at the workshops". (Audio 2, 3:43 – 4:04). The other teachers in the cluster group agreed with her.

Different approaches to teaching

Involvement in the project has encouraged teachers to adopt and contribute to a greater repertoire of innovative teaching methodologies. Five of the fifteen teachers across the three cluster groups talked about being introduced to different teaching methodologies at the workshops, and about how nervous they were the first time trying them out with their pupils. They commented on engaging in open discussions at workshops regarding the successes and challenges of implementing the various teaching methodologies, and in particular how these helped them to become more confident trying different teaching approaches. One teacher summed it up succinctly when he stated "I tried concept mapping with my pupils. It did not go very well. We discussed it next time [at next workshop] I made a few changes; it worked better a second time".

Such findings add further weight to the conclusions of a growing number of researchers (Cohen & Hill, 1997; Kennedy, 1998; Garet et al., 2001) - that in order for professional development of teachers to be effective, it needs to be concerned with enhancing teachers' science subject matter found on the curriculum i.e. is taught and learned in their classroom.

Q2: *To what extent has your view of teaching science changed as a result of your involvement in the project?*

All teachers in the three clusters indicated that the project had a positive impact on the way they teach science. Their responses to this question implied they were trying to move away from a teacher-centred approach, to a more pupil-centred approach.

Participants' answers suggest two broad categories of change in teachers' approaches to their work: hands-on activities, and more systematic pedagogical thinking.

Five of the fifteen participants from across the three clusters indicated that the greatest change in teaching science for them was the stronger emphasis on more open-ended practical work with their pupils (other participants were in agreement). Their responses outlined the importance of involving the children more in hands-on science and encouraging them to find out for themselves, rather than being told the answers by the teacher. For example:

> [prior to WSSP] I used textbooks a lot...when you experience the practical side of it [science at workshop] you are more confident going back to class...pupils enjoy it and they build up a camaraderie of working together.... you see a side of kids you would not normally see" (Audio 2, 1:40 – 2:15)

Three participants across two clusters revealed that prior to their involvement in the project they were excessively dependent on science textbooks and curriculum guidelines. All the other teachers in these two cluster groups were in agreement (this issue did not arise in the other cluster). Participation in the project helped them break this dependency and become a bit bolder in trying out hands-on activities and classroom discussion. The following points capture this very well: "since joining the project I have moved away from the textbook [science] and I have used many of the ideas I have picked up here [workshops]" (Audio 2, 0:20 – 0.:35), and "you must involve the children more, they must get more hands on, move away [the teacher] from the chalk and talk approach to teaching science" (Audio 1, 2:30 – 2:42).

Three of the fifteen teachers (one from each cluster group) discussed how the project encouraged them to actively reflect and reformulate their pedagogical thinking. One stated "I think more about the methodologies I use, rather than saying I have to do this and I will just do it in whatever way I can...I think in advance of how I am going to do it [science lesson] and how to avoid the pitfalls" (Audio 3, 1:22 – 1:41). Another teacher voiced a new awareness of the importance of probing children's ideas at the start and end of a science lesson: "concept cartoons are a fabulous idea for finding out children's ideas before a lesson or after a lesson for revision" (Audio 1, 1:15 – 1:23). The majority of teachers in each group were in agreement with these comments. These encouraging findings illustrate the kinds of shifts in professional thinking and action that the workshops promoted among the participating practitioners.

Q3: *To what extent have you introduced new science strategies into your classroom?*
All fifteen participants from the three clusters stated that they had introduced new science strategies to their classrooms as a result of their involvement in the project.
Two main areas were identified, open-ended investigations and innovative teaching methodologies.

For example five participants from across the three cluster groups indicated that they were now regularly using open-ended investigations rather than "recipe" type experiments with their pupils (majority of teachers agreed, none disagreed). One teacher put it very well when she talked about open-ended investigations, being a great innovation in her classroom. Prior to her involvement in the project she carried out experiments with her pupils that were "cut and dried". The pupils invariably knew what was going to happen. She suggested that open-ended investigations encouraged her pupils to enjoy debating possibilities, predicting outcomes, and developing a love for science.

Many participants talked of successfully using a number of innovative teaching methodologies in science lessons such as: concept cartoons, concept mapping, and Predict-Observe-Explain. The following statement is representative of teachers' comments: "I think concept cartoons are excellent, you can use them in so many ways...it [concept cartoons] creates so much debate" (Audio 1, 0:50 – 1:15). Another mentioned that he now uses more ICT in his science lessons "using heart monitors and temperature gauges [data logging equipment], the children absolutely love that...they are asking to do science now whereas before there would be moans and groans" (Audio 1, 5:47 – 6:08).

Q4: *Have you observed any changes in your pupils' attitudes toward science since your participation in this project?*
All fifteen teachers in the three cluster groups answered "yes" to this question. They all reported that the changes in attitudes were very positive. The participants identified two areas that helped to bring about this change including: pupils engaging in more hands-on activities, and teachers themselves being more confident teaching science. For example, four of the fifteen teachers (across three clusters) said their pupils requested more

science in school, five teachers indicated that pupils liked science more because they were doing more practical science in class. Not all the participants gave reasons why their pupils developed positive attitudes towards science lessons. However, they were in agreement with the reasons offered by the other participants. The following comments represent a sample of what teachers said about their pupils' attitudes towards school science: "they remind you at the start of the week that you have to do science with them", "they request it a lot more than they use to", "it is more of a hands-on subject for them now, whereas before I would ask them to take out their textbook and we would talk about science facts" (Audio 1, 7:42 – 7:58).

Two teachers from the same cluster discussed their change in confidence as an area that contributed to their pupils' attitudes to school science: "I think my children love science because I am more confident in teaching, it now....when you are more confident teaching it reflects on them" (Audio 2, 8:08 – 8:17). This is a very important finding as it enabled teachers themselves to see their lack of confidence as a disabling feature of teaching science.

7.2.2 Teachers' thoughts, opinions and impressions about WSSP as a model of professional development

Interview results regarding teachers' thoughts, opinions and impressions about WSSP as a model of professional development is based on their responses (see DVD, audio 1, 2, 3) to the following three questions:

- What did you gain most from your involvement in the project?
- What do you think are the characteristics of effective professional development?
- Were there any barriers associated with this professional development programme?

Q1: *What did you gain most from your involvement in the project?*

All fifteen participants interviewed commented, that they had benefitted from their involvement in the project. They identified three areas where they benefitted most: active engagement in hands-on open-ended investigations in the workshops, improvement in their confidence to teach science, and obtaining resources from the workshops.

For example, three teachers from across two clusters indicated that the active hands-on approach used in the workshops was of greatest benefit to them. The other participants in these two cluster groups agreed with them. The active hands-on approach used in the workshops allowed teachers the chance to experience practical science activities in a similar way to how their pupils experience them. It has led to a significant and sustained increase in hand-on activities in their teaching of science. Most believed that learning this way provided them with an enhanced understanding of the questions their pupils would come across when engaging in such activities. The following comments are representative of teachers' perceptions about experiencing an activity as a pupil learner: "the fact that we can come, engage in activities here [workshop], ask questions, means I am very confident going back to the classroom" (Audio 2, 0:58 – 1:10). "the practical things we do here [workshop], give you something to go back with... it is very simple … makes you more confident in the classroom, especially doing it ourselves first" (Audio 2, 4:42 – 5:15).

Two participants from the same two cluster groups mentioned above, identified feeling more confident when teaching science to their pupils, as being the greatest benefit for them (other participants in the two cluster groups did not agree or disagree). For example, one indicated that before participating in the project she would not understand the processes and outcomes of various science hands-on activities. She stated:

> I am more confident [post WSSP] in knowing what is meant to happen... sometimes I am doing experiments [pre WSSP] and I am actually not sure what should happen and why ... Because we have gone through things here [workshop] I know the outcomes and it makes me more confident (Audio 3, 1:54 – 2:10)

Overall, teachers in two cluster groups perceived the opportunity to carry out practical science activities in a manner similar to their pupils, as an important feature of a professional development programme.

Teachers in the third cluster did not mention the hands-on approach as a benefit for them. The only benefit commented on by participants in this cluster group was the availability of good resources – two teachers commented on this and the others agreed.

Q2: *What do you think are the characteristics of effective professional development?*

This section includes the most frequently discussed themes for effective professional development as viewed by teachers. The most frequently discussed themes included: duration of the professional development, amount of information received, relevance of the professional development, and collaboration.

Duration of professional development

The most frequent response by participants across the three cluster groups indicated that other professional courses they had attended were too short in duration and too overloaded with information. As one teacher put it "when the new curriculum was introduced it was one long day [in-service], everything was thrown at you like a wall and a lot of what was thrown did not stick" (Audio 2, 12:09 – 12:26). There was a strong consensus across the three cluster groups that the traditional type of in-service courses they had experienced did not allow them the opportunity to return to their classrooms and try out what they had learnt, or to discuss their practice at a follow-up workshops. Significantly, all participants spoke favourably of the WSSP model in terms of providing more welcome forms of continuing professional development. The following three comments clearly signify this, "because it [WSSP] was on-going you knew well if it [innovative approach] did not work out for you one time [in classroom] we could discuss this at the next workshop, or contact you" (Audio 3, 7:00 – 7:25), "this [WSSP] has a long-term approach and it is certainly superior to the short sharp shock approach" (Audio 2, 13:40 – 13:46) and "now that it [in-service] is coming at you in small manageable bits, more of it [information] is sticking... you get a chance to implement it straight away" (Audio 1, 2:25 – 12:45).

Content

Six respondents from across the three clusters indicated that they were overburdened with content at other professional development courses they had attended. They expressed a preference for the approach used by WSSP i.e. less in-depth science content and more hands-on experience; allowing them the opportunity to take what they learnt in the workshops back to their classroom, try it out with their pupils to enhance the teaching and learning of science. Responses included: "I was about to lose faith in professional development, the overload in a short period of time... this [WSSP] is more practical, not too much information.... you go away with an idea that you can work on with children in your school" (Audio 3, 6:40 – 7:03), and "in-service [pre WSSP] was heavy going, too much information in one day, too many ideas...at the end of the day you will probably not try any of them at all" (Audio 2, 12.50 – 13.24).

Collaboration

All of participants placed a strong emphasis on professional development providing opportunities for teachers to collaborate with each other, share ideas and partake in pedagogical discussions. The following remark typifies this view: "collaboration is extremely important; because of the isolation of working in small schools...meeting people who are like-minded...science is the thing that pulls us together" (Audio 3, 8:38 – 9:06). There was a general consensus across all three clusters that unlike other forms of professional development they had experienced, the WSSP model provided opportunities for collaboration. Comments include: "support, camaraderie, and a focus on science...you bring back other people's ideas to your own school" (Audio 3, 10:40 – 11.08) and "we have open discussions about teaching and learning at the workshops". One of the most experienced teachers (speaking on his own behalf) talked about the importance of professional development in the breakdown of teacher isolation. According to him, with the previous professional development courses he attended "you just received information from the course facilitator and you then went back to the privacy and isolation of your own classroom". He stated "an important aspect of professional development should be getting to know new colleagues, we can be very isolated out in small country schools...walking into other peoples schools helps you to get good ideas for your own school" (Audio 2, 15:34 – 16:56).

Relevance

All the teachers commented on the importance of making professional development relevant to their needs. The following comment is representative of what participants said: "I have attended a number of in-service courses where someone else [facilitator] just throws things [information] at you, you don't get a say in it". Three teachers across the three cluster groups suggested that one of the strengths of WSSP was that it gave them a sense of ownership of the professional development. Comments included: "this project was very relevant to our needs, we could choose the topics [science] on the programme, it was what we wanted to do...you never felt under pressure" (Audio 2, 14:48 – 15:18).

Q3: *Were there any barriers associated with this professional development programme?* When asked this question, time pressure and curriculum overload emerged as the most commonly cited factors to impede teachers carrying out new science strategies with their pupils, and attending professional development programmes. Nine of the fifteen participants indicated that time to attend the project, carry out follow-up activities with pupils and share with colleagues upon return to school, were factors that hindered to some degree, the success of this professional development programme. One teacher's comment succinctly sums up the general thinking here: "curriculum overloaded and finding time to attend these workshops are the biggest barriers" (Audio 3, 11:33 – 12:06). Three further teachers talked about time as a barrier to them carrying out hands-on activities with their pupils. One of them captured this view very well when he stated, "carrying out a hands-on activity can take all afternoon...need to block the timetable for it, this is not easy" (Audio 1, 8:14 – 8:48). In the Irish context the prevailing school culture is probably the greatest challenge to finding time for professional development. The rigid structure of teachers' work days, which sees the role of the teacher as "just" teaching their pupils, allows too little time for individual and collaborative work towards enhancing teaching and learning. Hogan et al. (2005) argue: "a difficult problem that confronts us here [Irish context] is the traditional assumption that a teacher's time-in-school is solely for the purpose of being in the classroom teaching the pupils" (Hogan et al. 2005, p. 8).

7.3 Monitoring project development

At the start of the intervention programme, all participating schools completed a survey which asked them to indicate the help they required from the project to enhance the teaching and learning of science in their classrooms. Schools were given a number of topics related to science education, and asked to prioritise the topics they would like to cover during the course of workshops (appendix G, p. 268). The same survey was administered a second time at the start of Year Two of the intervention programme (September 2009). Data collected from both surveys was very informative in helping to shape the emphasis of the WSSP programme. Teacher replies were categorised into two areas: knowledge of science and pedagogy. Responses from the schools prior to intervention revealed that the majority of them prioritised topics concerned with knowledge of science. Table 7.12 provides a summary of the number of teachers who prioritised (1 to 5) various topics at pre-intervention and at the end of Year One. For example, at the pre-intervention stage, fourteen schools placed “electricity/magnetism” in their top five list of priorities.

Table 7.12: Topics included by schools within their top five priorities (pre-intervention and end of Year One).

TOPIC	Pre intervention (n=15)	End of Year One (n=15)
Explanation of Scientific concepts	13	12
Electricity/Magnetism	14	00
How pupils learn (pupil preconceptions)	01	09
Forces	15	07
Heat	15	03
Living things	04	03
Sound/light	05	02
Use of ICT in science	00	03
Carrying out Investigations in science (fair test)	00	10
Sharing ideas and resources	04	11
Active teaching methodologies in science	00	09

Table 7.12 shows that pre-intervention, the vast majority of schools wanted the programme to help them develop their knowledge of science i.e. their top five choices of topics were all related to the issue of their own knowledge of science. The majority of these were concerned with their knowledge of physical science. This is consistent with the findings found in section 7.1.3 i.e. teachers having low confidence regarding physical science topics and difficulty teaching them.

The survey at the end of Year One revealed very different responses from the schools. Most significantly, there was a shift of emphasis from science content towards pedagogy. For example, nine schools included “how pupils learn” and “active teaching methodologies in science” and ten schools included “carrying out investigations in science” as one of their top five choices.

The dramatic change regarding “electricity/magnetism” (from 14 to 0) can be explained by the fact that in the first year of the programme the topic of electricity/magnetism was covered in the workshops. These results are very significant; they show that the participating teachers increasingly reflected on their classroom practice – seeing the importance of pedagogical knowledge as well as science knowledge.

Four schools requested help with developing their design-and-make skills and hands-on activities in the classroom. Five schools also asked for assistance with their classroom practice – requesting the researcher to come into their class to teach science, and/or observe them teaching science to their pupils. They also show that teachers developed a trust with the researcher (in his capacity as facilitator); so much so, that a number of them (nine participants) allowed him into the privacy of their classroom to contribute to their classroom practice.

Reflection monitoring template

At end of Year One the participating teachers were asked to complete an open-ended reflection template (appendix H, p. 269). Only 15 of the 24 participants returned the completed reflection template (all 15 were teaching pupils in 4^{th} to 6^{th} class). The participants were asked four open-ended questions.

- What have been the greatest benefits for you personally as a result of your work with WSSP?
- What benefits have there been for your pupils as a result of your work with WSSP?
- Has your teaching approach to science changed since your involvement with WSSP?
- Has your confidence in teaching science changed since your involvement with WSSP?

Q1: *What have been the greatest benefits for you personally as a result of your work with WSSP?*

The responses from all fifteen teachers indicated that they benefitted professionally as a result of their involvement with WSSP. The greatest benefit identified by eleven respondents was the benefit to their daily teaching – including their enhanced knowledge of science, their familiarity with a range of new teaching approaches and their hands-on experience in carrying out these approaches, supported by the workshops. A further four teachers identified the greatest benefit as the recurrent interaction they experienced with teachers from other schools. Comments included: “I don’t feel restricted [from interacting with colleagues] anymore by my lack of science knowledge”; “greatest benefit for me has been interacting with other teachers, sharing ideas, resources and frustrations”; “the greatest benefit of WSSP is that it has given me the confidence as a teacher to try different things in science and to try different teaching and learning experiences with my class”.

Q2*: What benefits have there been for your pupils as a result of your work with WSSP?*

All the participants commented on the positive influence of the project on the quality of their pupils’ learning experiences of science. Seven respondents indicated that their pupils were more interested in science and enjoyed it more. The other eight teachers revealed that their pupils were more involved in hands-on activities as a consequence of their involvement in the project. The majority of responses to this question revealed a positive correlation between the benefits of the project for pupils and those for teachers. Examples of this include: “my pupils have benefitted from me gaining a greater confidence in my teaching ability”; “there is a greater focus on the learning of science...more active engagement in science activities on the part of the pupils”; “children have more opportunities to talk during science lessons, asking questions on the activities” and “pupils carry out more hands-on activities during lessons”.

Q3: *Has your teaching approach to science changed since your involvement with WSSP?*

The overwhelming answer to this question was “yes” the respondents identified two areas of change in their teaching approach to science: greater use of hands-on science activities (eleven respondents) and a more pupil centred approach to teaching (four respondents). These changes are most tellingly illustrated by some of the written comments of teachers, including: “I don’t avoid science topics I am unsure about anymore...I give more time to hands-on experiments and more time for discussion”; “I have used a more exploratory approach and I am more open- minded on outcomes”; “I am much more organised, as a result this leads to better teaching”; “yes, I have moved away from the theory and book learning, the children are learning much more through discovery and investigations”.

Q4: *Has your confidence in teaching science changed since your involvement with WSSP?*

All the participants stated that their confidence in teaching science had increased as a result of their participation in the project. A number of respondents gave more than one reason why this had occurred. Nine respondents indicated that their increase in confidence was attributed to a deepening of their knowledge of science. Ten respondents identified the carrying out of hands-on activities at the workshops as the reason for their increased confidence in teaching science. The following comments succinctly capture the general thinking here: "I am more confident now teaching science, especially practical science" "yes, most definitely. My knowledge of science has been broadened, and the notion that the teacher must have all the right answers is not to the forefront of my mind". These findings are very encouraging and further illustrate the kinds of shifts in professional thinking that the project cultivated among the participating practitioners.

7.4 Teacher understanding of basic science concepts

As well as trying to develop teachers' attitudes towards school science and attitudes to teaching science, WSSP also set out to develop the conceptual understanding of science itself among the participating teachers. The participants were presented with a series of short questions (appendix F, p. 266) to investigate their understanding of basic science concepts found in the primary science curriculum. The questions were administered in September 2008 and June 2010. Questions on this test were designed specifically to draw out misconceptions that might be held by teachers, especially in areas of the curriculum that have been shown to cause difficulty for teachers, such as energy and forces (Jarvis et al., 2003). They also related to objectives in the different strand units of the Science Curriculum (DES, 1999a).

All the questions in the test (appendix F, p. 266) were true/false questions and therefore teachers could only have received a correct or incorrect answer for each question. The statements regarding the teachers' scientific content knowledge provide interesting data in terms of the effects this intervention programme has had on the development of their scientific content knowledge. Table 7.13 provides a summary of the different statements related to aspects of scientific content knowledge, and the percentage of teachers who responded correctly to each statement at pre-intervention and post-intervention stages.

Table 7.13: Percentages of teachers responding correctly to questions of basic science concepts (before and after intervention programme)

Statements (True or False)	Pre Intervention (% Correct)	Post Intervention (% Correct)	Change + / -
Gravity only acts on objects when they are falling	68	95	+
Friction only acts on moving objects	53	89	+
Heavy things fall to the ground quicker than light things	21	100	+
Objects which are sitting still have no forces acting on them	100	100	
The moon is luminous	63	100	+
Sound only travels through air, not solid objects or liquids	95	100	+
You only hear when you listen	95	100	+
Higher notes are louder than low notes	63	89	+
Sound makes vibrations	53	84	+
Less current returns to the battery when it passes through say a bulb (it is used up)	26	89	+
Current flows from battery to bulb but not from bulb back to battery	53	100	+
Gases do not have mass	84	100	+
If an object is at rest no forces are acting on it	95	100	+
Wood floats and metal sinks	58	100	+
All metals are attracted to a magnet	69	100	+
Heat travels from a cold body to a hot body	74	100	+
If two objects have the same temp then they have the same amount of heat	68	95	+
Correct drawing of how we see light (two lines with arrows)	47	100	+
Which of the following are plants?	**(% Correct)**	**(% Correct)**	
A tree in the ground	89	100	+
A potato growing in the ground	68	100	+
A daisy growing in the ground	84	100	+
A thistle growing in the ground	84	100	+
Which of the following are animals?			
A fish in a pond	58	100	+
A dog found around the house	100	100	+
A human being	89	100	+
A common household fly	58	100	+
A snake	63	100	+
A spider	68	100	+

(N = 19) Note: the teacher numbers in the table have been adjusted as only 19 teachers completed pre intervention and post intervention tests on responses to science concepts

Table 7.13 shows that prior to WSSP; many of the teachers had misconceptions in a number of key areas, especially forces and electricity. These responses point to a revealing lack of knowledge and understanding of basic concepts underpinning science. They also endorse the concerns articulated by Matthews and Kenna (1996) regarding the implementation of primary science in Irish primary schools. Matthews and Kenna stress:

> Without an understanding of basic aspects of physical science it is impossible for teachers to make valid judgements about the content of the lessons they will teach, about the depth of understanding that they should expect their pupils to achieve, and about the level of explanation they should provide (p. 28).

Post-intervention, there was a dramatic increase in the number of teachers who gave correct answers to the questions, especially in the physical science area.

A close examination of results reveals:

- Teachers' understanding of how electricity moves was poor prior to their involvement in the intervention programme. Only 26% of the teachers disagreed with the statement "less current returns to the battery when it passes through say a bulb" (many of them believing it was used up). 53% disputed "current flows from battery to bulb but not from bulb back to battery". Post intervention, this changed to 89% and 100% respectively.

- Many teachers had problems understanding gravity and friction. Prior to intervention, only 68% of teachers disagreed with the statement "gravity only acts on objects when they are falling"; 53% that "friction only acts on moving objects"; and only 21% that "heavy things fall to the ground quicker than light things". At the end of the intervention this changed to 95%, 89% and 100% respectively.

- Surprisingly, in the pre-test, approximately one-third of the teachers did not recognise spiders, flies and snakes as animals. 32% of them did not identify potatoes as plants. Post-test, all these misconceptions were rectified.

- Furthermore, in the pre-test, less than 50% of the teachers were able to draw the correct scientifically accepted model of vision (appendix F, p. 266). Post-test, this misconception was rectified in all cases.

It is apparent from examination of the pre- and post-test scores, that there was a decisive improvement in teachers' scientific content knowledge in all questions where there could be improvement. As none of the participants were involved in any other science professional development while participating in WSSP, these results confirm that the WSSP intervention programme addressed some of the long standing deficiencies. However, while these results are encouraging, a note of caution, three of teachers revealed inaccurate understandings of aspects of the *Energy and Forces* section of the primary science curriculum in the post-intervention test. The findings appear to indicate that these teachers still hold similar misconceptions as some of the children they teach. This concurs with research carried out by Jarvis and Pell (2004). They found that even after providing a cohort of primary teachers with an intense professional development programme in physical science concepts; a number of them still retained the misconceptions they held prior to the programme. A possible reason for this was that it was not possible to spend enough time on these concepts. It is the researcher's considered belief that some teachers need much more time than others to understand science concepts.

7.5 Review of most salient issues

This study commenced six years after the implementation of science as a compulsory subject in the revised primary school curriculum. It shows that after teaching pupils primary science for six years, a lack of confidence and expertise in teaching primary science has seriously curtailed the capabilities of teachers in this important aspect of the curriculum (and there is no reason to believe that those in the current study were untypical of Irish primary teachers more widely). It also shows that an innovative participatory model of professional development can bring about positive changes in teachers' confidence and competence in the teaching of science, in teachers' attitudes to teaching science, and not least, in teachers' classroom practice. The main points to emerge from this chapter in relation to the first aim of this study are discussed in this section i.e. to investigate the extent to which the WSSP model of professional development can help bring about improvements in confidence, competence, attitudes and levels of knowledge among the participating teachers, where the teaching of science is concerned.

The results of the study indicate that at the start of their participation in the programme, the majority of teachers had low confidence in their ability to teach primary science effectively to their pupils. Many of the participants did not understand a number of the science concepts essential to the teaching of primary science. In fact, a surprising number of them had the same misunderstandings of science concepts as their pupils. This is not an unexpected disclosure, considering that the only professional development in science teaching for the majority of the participants had been the two days of in-service during the implementation of the new curriculum. These results are consistent with the literature (discussed in Chapter Four), suggesting that most primary teachers are not adequately prepared to teach primary science effectively. The study has also revealed that the kind of professional development programme associated with the WSSP project, made some decisive advances in developing teacher confidence, understanding of science and skills in teaching science.

Before intervention, twenty-four participants rated their confidence to teach science lower than all the other curriculum subjects. Post-intervention, this difference was virtually eliminated. An area of concern that the study revealed was the clear differences in teachers' confidence in teaching different content areas. Pre-intervention, participants rated themselves very confident teaching biological sciences but had low confidence levels teaching physical science. Post-intervention, participants became much more confident teaching a number of conceptually challenging physical science topics.

As well as gaining in confidence, teachers made significant gains in their understanding of science concepts, especially those concerned with physical science. Harlen (1997) claims such gains in teachers' understanding of science concepts is a fundamental part of improving the quality of teaching and learning in science. Pre-intervention, teachers' understanding of science concepts varied widely. Some had the same misconceptions as their pupils, while others had a good understanding of the science concepts they were expected to teach to their pupils. Post-intervention, the degree of understanding of science concepts also varied from teacher to teacher. Some teachers picked up the science concepts quickly; others needed a lot more time. Even though the professional development lasted two years a small number of teachers still had a number of misconceptions regarding some science concepts. The teachers concerned were not aware that they had these misconceptions and they felt confident in teaching science to their pupils. The findings from table 7.12 show that at least two of the nineteen teacher respondents did not develop a clear understanding of some of the concepts associated with physical science. Thus, an increase in confidence is not necessarily accompanied by increased understanding.

An area of concern at the start of the project included the narrow range of innovative teaching methodologies teachers used when teaching science. Many of them did not use methodologies that encouraged their pupils to carry out open-ended hands-on activities and develop an understanding of the science concepts related to these activities. Other areas of concern included: low teacher confidence in developing pupils' scientific skills, design-and-make skills, and science teaching skills. This finding concurs with the suggestion of Appleton (2003) who maintains that a way for teachers to cope with science teaching in primary schools is to utilise a set of "activities that work", namely activities the teachers feel secure with, have taught previously and that have fairly predictable outcomes in providing pupils with science content knowledge. Post-intervention, there was a significant increase in the teachers' confidence levels in all the areas discussed above.

The findings also show that prior to their involvement in WSSP, most of the participating teachers were over dependent on the science textbook in science classes (further evidence of this is found in Chapter Nine, section 9.3.1). In 2005 the Department of Education and Science published the Curriculum Implementation Evaluation (CIE) Report. It found that in classrooms where textbooks exercise an overriding influence on teaching and learning "teaching and learning methodologies were restricted, and the essential emphases of the curriculum were not accorded due prominence" (DES 2005, p. 49). Post-intervention, there is clear evidence that teachers became progressively less dependent on the science textbook and used a greater variety of innovative teaching methodologies with their pupils.

Correlation analysis indicated some relationships between teacher confidence in teaching science and factors such as: the participating teachers' gender, teaching experience, and qualification in science. Some examples include: pre-intervention, female teachers were less confident than their male counterparts in developing pupils' scientific skills and design-and-make skills. Pre-intervention, most experienced teachers and least experienced teachers were similar in their confidence in all subscales asked. However, post-intervention the most experienced teachers made statistically significant improvements in all subscales whereas, the least experienced made no significant improvements at all.

The responses to interview questions clearly indicated that the approach taken by this professional development project has led to encouraging advances in the teaching of science in the classrooms of the participants. Teachers talked about doing more hands-on activities and trying different teaching methodologies with their pupils. Most importantly, teachers spoke about the positive impact of the WSSP workshops on their pedagogical attitudes, capabilities and practices, and on the quality of their pupils learning experiences. This coincides with the view of Guskey (1986), who argues that professional development is more effective when teachers are encouraged to try out new practices with their pupils and observe the effects, rather than trying to change teachers' attitudes first in the hope that this will bring about a change in practice. The teacher participants commented on the inadequate professional development they received prior to WSSP. The characteristics of effective professional development identified by the teachers were, in general, the same ones identified in the literature review (Hawley & Valli, 1999; Garet et al., 2001; Guskey, 2003; and Hogan et al., 2007) as significant factors of effective professional development design. The teachers wanted professional development courses that were: on-going, relevant to their needs, and collaborative in nature. By far the most criticised characteristic of professional development cited by the participants in this study was the lack of adequate time – they felt they needed more time to carry out new teaching methodologies with their pupils and to reflect on and evaluate the effects on their classroom practice. Teachers also criticised the overloaded curriculum (12 subjects) which draws diversely upon their energy, making it difficult for them to meaningfully reflect on teaching and learning processes in their classrooms. In saying that, the majority of teachers did carry out innovative teaching methodologies with their pupils and engaged in meaningful reflection with colleagues during the workshops.

Most significantly, their experiences with the WSSP model of professional development were very positive. They commended a number of aspects of the model, in particular: the on-going nature of the workshops that allowed time for them to try out ideas between sessions; the hands-on nature of the workshops that made science relevant to their own classroom experiences; and their experiences of sharing ideas and resources and engaging in open pedagogical discussion. All of the above contributed to an increase in their confidence and competence in teaching science to their pupils.

Chapter 8
Presentation and Analysis of Research Data (Part 2)
Findings from Pupils

Introduction

This chapter is concerned with presenting and analysing data from the pupil pre- and post-intervention questionnaires for all participating pupils, in the fifteen schools. The questionnaires were administered in October 2008 and again in June 2010. Findings from the data are discussed in relation to the second aim of the study, i.e. investigating the extent to which pupils' attitudes towards school science are influenced by changes in teachers' pedagogical approaches. More specifically, the findings address the following two research questions:

- What changes in pupils' attitudes towards school science occurred during the study?
- What changes in pupils' participation and collaboration in hands-on science activities occurred during this study?

The chapter is divided into three parts. The first part (section 8.1) profiles the participating schools and pupils (section 8.1.1) and presents and analyses findings from the attitude scales in the pupil questionnaire (pre/post-intervention). Questionnaire scales include: pupils' attitudes to school (section 8.1.2); pupils' attitudes to school science (section 8.1.3); pupils' attitudes regarding science experiments (8.1.4); and, pupils' attitudes towards science content areas (section 8.1.5). The second part (section 8.2) investigates gender differences across all scales of the questionnaire. The final part (section 8.3) provides a summary of the salient issues.

8.1 Pupil questionnaire

The responses to the closed questions on the pupil questionnaire (pre/post) were analysed statistically using SPSS Version 15. Parametric tests were carried out, including t-tests, and correlation analysis. Reliability analysis of all grouped Likert items were carried out calculating Cronbach's alpha coefficient. This yielded values of 0.7 or higher. This was deemed reliable for attitudinal responses (Cohen, Manion & Morrison, 2000, p. 506). All sections of the pupil questionnaire used a 3 point Likert scale of smiley faces, representing a positive response, not sure response, and negative response. The questionnaire was divided into five subsections. Each one of these will be dealt with individually.

8.1.1 Profile of schools and pupils

As teachers in fourteen of the participating schools taught pupils in multi-grade classes, it was decided that pupils from 4^{th} to 6^{th} class would participate in this study. A total of 281 pupils completed the pre-intervention questionnaires in October 2008. However, only 269 pupils completed the post-intervention questionnaire in June 2010. The reason for this was that on the day that the post-intervention questionnaires were administered in late June 2010 a number of pupils were absent from the various schools. Table 8.1 provides data on school type and pupil profile. Male pupils made up 51% of the pupil population. The number of pupils in 4^{th}, 5^{th}, and 6^{th} class was reasonably proportionate (29% : 36% : 35%).

Table 8.1: Profile of participating schools and pupils

	Frequency	Percentage
Size of School		
00 – 50 pupils	07	47
50 – 100 pupils	07	47
100 – 150 pupils	00	00
Greater than – 150 pupils	01	06
Gender of School		
All girls	00	00
All boys	00	00
Mixed	100	100
Gender of Pupils		
Male	143	51
Female	138	49
Class profile of pupils		
4^{th} class	80	29
5^{th} class	101	36
6^{th} class	100	35

8.1.2 Pupil attitudes to being in school

The first scale of the questionnaire asked pupils what they think about being in school. The rationale behind this was to allow pupils' attitudes to science to be put in the context of their overall school experience. Pupils were asked seven questions in this section, using a three point Likert scale (smiley faces). A score of 1 indicates a negative response to the question and a score of 3 indicates a positive response. Results of the pre- and post-intervention pupil responses are shown in table 8.2.

Table 8.2: Pupils' attitudes about school (before and after intervention)

	Pre-intervention (N = 281)		Post-intervention (N = 269)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deivation**	**Sig**
What I think about being in school					
I like school	2.32	0.756	2.34	0.760	.783
I'm happy at school	2.68	0.542	2.68	0.556	1.00
I work hard at school	2.79	0.470	2.76	0.467	.533
I find school interesting	2.38	0.669	2.31	0.724	.210
I enjoy doing school work	2.04	0.792	1.96	0.773	.161
I enjoy working on my own	2.85	0.425	2.91	0.319	.043
I enjoy working with friends at school	2.22	0.803	2.15	0.792	.212

** $p < .01$ significant difference paired *t*-test.

High mean scores (positive) at pre-intervention, show that pupils involved in this study had in general, positive attitudes about being in school, especially in the areas of "I'm happy at school", "I work hard at school", and "I find school interesting". The results also show that there were no statistically significant differences in pupils' mean scores pre- and post-intervention. Post-intervention, the pupils as a whole showed a slightly more positive attitude under two headings, a slightly more negative attitude under four headings and no change under the remaining heading; but any changes were so small as to be insignificant. These responses regarding pupils' attitudes to school are contrasted with pupils' attitudes towards science at school in the next section.

8.1.3 Pupil attitudes to school science and science

This part of the survey asked pupils to respond to four questions relating to their attitudes to school science and two questions relating to pupils' perceived difficulty with science, pre- and post-intervention, using a three point Likert scale (smiley faces). A score of 1 indicates a negative response to the question and a score of 3 indicates a positive response. The results are presented in table 8.3.

Table 8.3: Pupils' attitudes about school science (before and after intervention)

	Pre Intervention (N = 281)		**Post Intervention (N = 269)**		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
What I think of science at school					
School science is easy	2.40	0.704	2.46	0.655	.300
School science is interesting	2.65	0.602	2.71	0.557	.177
I like science better than other subjects	2.10	0.799	2.26**	0.759	.010
I look forward to science lessons	2.60	0.595	2.60	0.636	.873
What I think about science					
You have to be clever to do science	1.77	0.837	1.59**	0.781	.003
Science is just too difficult	1.42	0.652	1.29**	0.567	.007

** $p < .01$ significant difference paired *t*-test.

High mean scores (positive) at pre-intervention, show that prior to intervention pupils generally had a positive disposition towards school science. Pupils had high mean scores (positive) regarding the items: "school science is interesting" and "I look forward to science lessons" (2.65 and 2.6 respectively). However, pupils had a mid-range mean score for the item "I like science better than other subjects". Post intervention, there was a statistically significant difference (positive) in pupils attitudes to the item; "I like science better than other subjects". Closer inspection of this difference shows that prior to intervention 64% of all pupil respondents stated that they liked science better than any other subject in school. Post-intervention this increased to 70% of all pupil respondents. Although this is only an increase of 6% it is a very important finding for two main reasons:

- International research (Osborne et al., 1998; Murphy & Beggs, 2001; Pell & Jarvis, 2001) shows that pupils' attitudes to school science tend to deteriorate as they progress through primary school. Murphy and Beggs (2002) have proposed a number of factors to explain this deterioration, including: ineffective teaching, heavy content of curriculum, national tests, and perceived difficulty of science. The factors that this study could influence were ineffective teaching and perceived difficulty of science. Murphy and Beggs suggest that over the last decade a relationship has been drawn between teachers' lack of confidence and limited science background knowledge and pupils' attitudes towards science education (p. 14).

- It must be taken into consideration that science is only one of twelve subjects found on the primary curriculum. Thus, an increase of 6% in the number of pupils who prefer it to other subjects is a very positive result.

Table 8.3 also shows that post-intervention, there was a statistically significant change in pupils' attitudes regarding the Likert items: "you have to be clever to do science" and "science is just too difficult". Figure 8.1 shows that pre-intervention, 28% of all pupil respondents answered "yes" to the item "you have to be clever to do science", and 48% answered "no". Post-intervention, the number who answered 'yes' decreased to 16% and the number who answered "no" increased to 60%.

Figure 8.1: Pupil responses to item: you have to be clever to do science (pre/post-intervention).

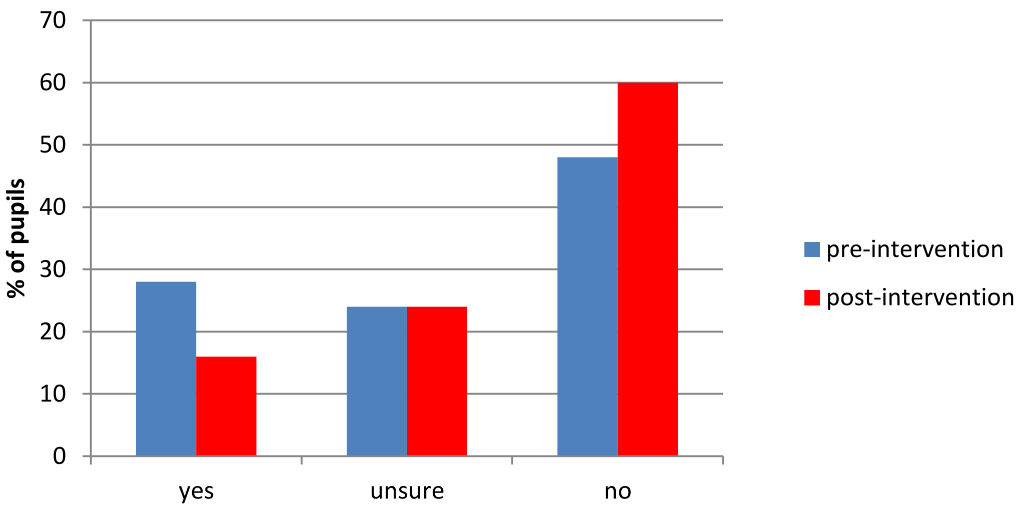
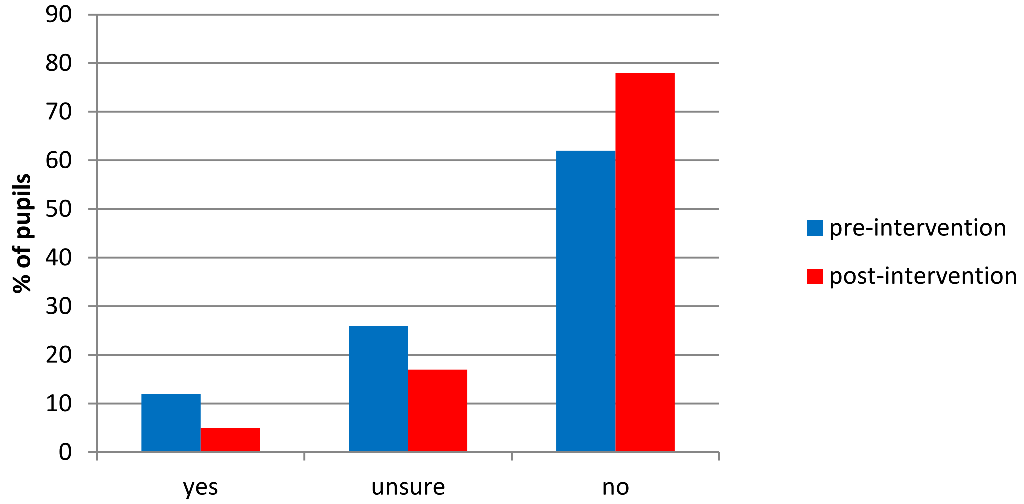


Figure 8.2 shows that pre-intervention, 12% of pupil respondents answered "yes" to the question "science is just too difficult", and 62% answered "no". Post-intervention, the number of those who answered "yes" decreased to 5% and the number who answered "no" increased to 78%. This is a very important finding, as according to Osborne et al. (2003) the perceived difficulty of science is a significant factor regarding pupils' attitudes and uptake of science subjects. Furthermore they stress that if pupils perceive it as difficult, only able pupils will choose it (p. 1070).

Figure 8.2: Pupil responses to item: science is just too difficult (pre/post-intervention)



Pupils' responses to the open questions gave a greater insight into their attitudes towards school science. Pupils were asked, "what is your least favourite science lesson, and why?". Prior to intervention 49 pupils said they had no least favourite science lesson, post-intervention this increased to 79 pupils (see table 8.6, p. 160). This clearly indicates an increase in the number of pupils with positive attitudes towards school science post-intervention. It can be concluded from all these findings that the intervention programme had a substantial positive impact on pupils' attitudes to school science.

8.1.4 Pupils' attitudes to science experiments

The Primary Science Curriculum teacher guidelines (DES, 1999b) encourage an exploratory approach to teaching science enabling children to "undertake practical activities... and open-ended investigations" (p. 53). The intervention programme placed a very strong emphasis on encouraging teachers to carry out hands-on activities with pupils. The third scale on the pupil questionnaire asked pupils what they enjoyed most about science experiments. The researcher used the term "experiment" in the questionnaire as it was felt that the pupils would be familiar with this term when considering practical science. For the purpose of this study, science experiments include those carried out by the teacher as well as by the pupil. Any of the following are considered as science experiments: hands-on science, investigations, practical work, teacher demonstrations and design-and-make activities. Pupils were asked a total of nine Likert items using a three point Likert scale (smiley faces). A score of 1 indicates a negative response to the question and a score of 3 indicates a positive response. Table 8.4 shows the mean rating scores for each of the nine questions asked in this section.

Table 8.4: Pupils' attitudes regarding science experiments (before and after intervention)

	Pre Intervention (N = 281)		Post Intervention (N = 269)		
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Sig**
I enjoy science experiments when					
I do experiment myself	2.18	0.779	2.09	0.852	.122
I do experiment with friends	2.75	0.588	2.82	0.497	.126
I watch the teacher doing experiment	2.40	0.815	2.34	0.804	.144
I plan my own experiment	2.33	0.758	2.23	0.805	.067
The teacher tells me what to do	2.42	0.753	2.29	0.800	.033
Finding out why the experiment worked	2.33	0.860	2.73**	0.536	.000
We go outside classroom to do science	2.75	0.527	2.80	0.516	.222
I choose my own equipment	2.46	0.705	2.41	0.727	.424
I design and make my own things	2.55	0.730	2.63	0.660	.152

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, pupils had high mean scores (positive) regarding: "working with their friends", "watching the teacher demonstrating an experiment", and "going outside to do science". However, they had a lower mean score regarding: "doing an experiment myself". Post-intervention, there was a statistically significant difference in pupils' attitudes toward: "finding out how an experiment works" (2.33 to 2.73). An important finding discussed in Chapter Seven showed that the approach taken by the WSSP project had a significant influence on the teaching and learning of science in the classrooms of the participants. It is more than likely as a consequence of this, that pupils' attitudes to hands-on activities have changed. This is a major finding as WSSP placed a strong emphasis on a pupil-centred approach to science practical work, it helped teachers to encourage their pupils to carry out open-ended investigations and discover for themselves what happens during investigations. Mean scores of the other items in the *pupils*' *attitudes to science experiments* section, did not appear to diverge much between pre-intervention and post-intervention. However, there was a very slight, but statistically insignificant decrease in mean score regarding pupils' attitudes to: doing "experiments on their own", "watching the teacher doing an experiment", and "teacher telling them what to do". There was an increase in mean score regarding pupils' attitudes to: "doing experiments with friends". Findings from table 8.4 indicate that there was very little change in the pupils' enjoyment of science experiments as a result of the intervention programme except in the area of "finding out how an experiment works".

The responses to these Likert items provide only attitudinal data about hands-on science. Closer scrutiny of pupils' responses to the open-ended questions revealed information regarding their involvement in hands-on activities. The final question on the pupil questionnaire asked the pupils to draw a picture of themselves and their class doing science at school. These drawings provide evidence of the positive impact of the intervention programme on pupils engaging in hands-on science. Pre-intervention, the number of drawings showing pupils engaging in hands-on activities was 164 (58%). This result concurs with findings found by Varley et al. (2008). Their study focused on children's experiences of, and attitudes towards science in Irish primary schools. In Varley's study, over a thousand children were asked to draw a picture of themselves in science class, 57% drew pictures of themselves engaging in hands-on activities. Post-WSSP, the number of pupils drawing pictures of themselves engaging in hands-on science increased to 200 (74%). Examples of pupils' drawings are shown in figures 8.3 and 8.4.

When pupils were asked the open-ended question "what is your favourite science lesson, and why?" their attitudes towards, and experience of carrying out hands-on science became evident. Prior to intervention 47 pupils (17%) stated that their favourite science lesson involved them doing experiments and making things for themselves. Post-intervention this number increased to 74 pupils (28%) (see table 8.5).

These findings from pupils' responses to Likert items, open-ended questions and drawings provide encouraging evidence to show that the intervention programme had a positive impact on the number of pupils engaging in hands-on activities.

Table 8.5: Pupils' favourite science lesson. Reasons why they enjoyed it (before and after instruction)

	Pre intervention (n = 281)	Post intervention (n = 269)
Reasons given by pupils as to why they enjoyed their favourite science lesson include:	**Number of Responses**	**Number of Responses**
Fun/interesting	124	104
Hands-on/experiment/design-and-make	47	74
Observations/events	48	29
Groups/friends	21	43
Learning/learning new things	20	21
Like science/topic	06	08
Don't know/blank	19	09
Outdoor events (garden/trip)	08	06
Messy	03	06
I did not do it before	03	00
It is easy	02	01
Talking about science	02	00
Everyone got a turn	01	02
Mixed art with science	01	00
Working alone	01	02
Use internet	01	00
No writing	01	00
Teacher not telling you what to do	00	03
Reading about science	00	01
Helping other pupils	00	01

Totals are different for pre- and post-intervention because when answering this question some pupils did not confine themselves to one item

Table 8.6: Pupils' least favourite science lesson. Reasons why they did not enjoy it (before and after instruction)

	Pre intervention (n = 281)	Post intervention (n = 269)
Reasons given by pupils as to why they did not enjoyed their least favourite science lesson include:	**Number of Responses**	**Number of Responses**
Boring/not interesting/ no fun	83	67
Blank/ not sure/ don't know	73	30
Enjoyed all science lessons	49	79
Experiment did not work/nothing happened	17	30
Unpleasant/smelly/messy	07	19
We did not do experiments	02	03
Teacher demonstration/ watching	10	05
To difficult/confusing	11	14
Don't like this topic	12	07
Time – lasts too long	09	08
Too easy	04	06
Wet and mucky	00	03
We did it before	00	04
Too much writing	03	00
Too much work	05	00
Too much reading	03	01
Working on my own	01	00

Totals are different for pre- and post-intervention because when answering this question some pupils did not confine themselves to one item

There is evidence that pupils develop positive attitudes to science when the amount of investigative practical work they engage in is increased. Research by Murphy and Beggs (2001) found that when primary school children were asked what they like best in science, they most frequently replied: doing experiments and finding out things. The increase in hands-on science as a result of the intervention programme may explain why there was no deterioration in pupils' attitudes to school science as they got older. These findings clearly indicate that the intervention programme had a strong positive impact on pupils' attitudes towards, and engagement in, hands-on science activities.

Figure 8.3: Pupils making electricity circuits

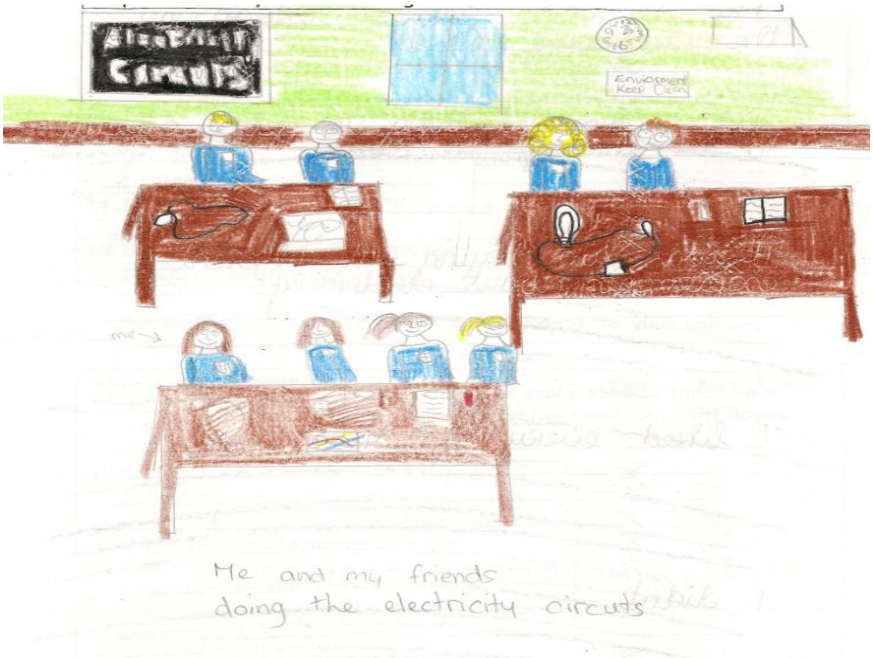


Figure 8.4: Pupils dissecting fish

8.1.5 Pupils' attitudes to science content

The fourth scale of the questionnaire asked pupils to show whether or not they liked, or disliked, learning about different science topics. Pupils were asked a total of eighteen questions based on the four different strands of the science curriculum: living things, energy and forces, materials, and environmental awareness and care, using a three point Likert scale (smiley faces). A score of 1 indicates negative response to the question and a score of 3 indicates a positive response. Table 8.7 shows the mean value scores for each of the content areas pre- and post-intervention.

Table 8.7: Pupils' attitudes towards science content (pre- and post-intervention)

	Pre Intervention (N = 281)		Post Intervention (N = 268)		
	Mean	**Standard Deviation**	**Mean**	**Standard**	**Sig**
I enjoy learning about					
Insects and mini-beasts	2.15	0.838	2.04	0.813	.064
How human body works	2.57	0.640	2.56	0.698	.822
Plants and how they grow	2.35	0.766	2.33	0.814	.731
How to look after environment	2.57	0.623	2.49	0.690	.086
Keeping fit and healthy	2.75	0.518	2.71	0.591	.318
Saving energy and recycling	2.41	0. 727	2.66**	0.563	.000
How sound travels	2.49	0.674	2.43	0.735	.284
Magnets	2.59	0.644	2.55	0.704	.415
Electricity, batteries, bulbs & switches	2.50	0.690	2.44	0.735	.273
Heating and cooling things	2.36	0.744	2.26	0.788	.068
Light, mirrors and shadows	2.42	0.722	2.39	0.754	.571
How machines work and move	2.51	0.695	2.51	0.747	.942
How we heat our homes	2.48	0.689	2.52	0.711	.501
Inventions and discoveries	2.68	0.556	2.69	0.572	.791
Materials we use to make things	2.56	0.659	2.54	0.699	.737
Solids, liquids and gases	2.51	0.679	2.50	0.716	.887
When you mix things together	2.79	0.488	2.84	0.461	.288

** $p < .01$ significant difference paired *t*-test.

Pre-intervention, pupils had high mean scores (positive attitudes) regarding the four strand content areas. Post-intervention there was only one statistically significant difference (positive) – in pupils' attitudes towards "saving energy and recycling". Mean scores of the other items in attitudes about science content section did not statistically diverge much between pre-intervention and post-intervention. These findings show that there was very little change in the pupils' attitudes to learning about different science topics as a result of the intervention programme, except in the area of "saving energy and recycling". In fact close inspection of table 8.7 shows a statistically insignificant lowering of mean scores for some items post-intervention e.g. "insects and mini-beasts" and "how sound travels".

The Likert scale questions only provide attitudinal data regarding pupils' learning about different strand areas. They do not let the researcher know whether or not the pupils actually learned about these topics in science class. Responses to the open questions: "what is your favourite lesson?" and "why did you enjoy it?" gave deeper insights into the topics pupils enjoyed doing in science class. Findings were coded according to content strand where appropriate (see table 8.8).

Table 8.8 Science content strand areas written by pupils in response to question "what is your favourite science lesson and why" (before and after intervention)

	Pre intervention	Post intervention
Science content strand area	**Number of Responses**	**Number of Responses**
Energy and forces	109	154
Materials	54	50
Animals and plants	47	34
Environment	12	09
Total	**222**	**247**

Totals are different for pre- and post-intervention because when answering this question some pupils did not confine themselves to one item

Findings from table 8.8 show a 50% rise in the number of pupils (post-intervention) whose favourite science lesson involved the strand unit, "energy and forces". This is not surprising, and is clearly as a result of their teachers' participation in the project. The WSSP workshops placed a strong emphasis on this strand unit, participants carried out many hands-on activities in this strand area. On the one hand, this finding is very encouraging, as it shows that WSSP had a significant impact regarding the teaching of physical science in the participating schools, and as a result, pupils are engaging in hands-on science representing a range of physical science topics. However, a concern here is that two content strand units "living things", and "environmental awareness and care" actually declined post-intervention.

Evidence from pupils' drawings of themselves doing science shows that they experienced a wide variety of topics across the science content strands: "living things", "energy and forces", and "materials" post-intervention. Prior to WSSP pupils drew and wrote mainly about learning topics such as electricity, sinking and floating and how the body works. Post-intervention, there is evidence that pupils were taught various other topics such as microorganisms, plants, gardening, materials, light, sound, gravity as well as those mentioned previously.

Additional statistical analysis was conducted, to investigate if there were any significant differences in the patterns of responses from the gender sub-group within the total group of pupils who participated. A correlation analysis between pupil attitudes to learning science and gender was carried out.

8.2 Gender issues

Gender is not one of the main areas of focus for this study. However, it is important to recognise that it is a noteworthy influential factor on pupils' attitudes towards school science (Pell & Jarvis, 2002, p.52).

Tables found in appendix K (p. 274) show that prior to intervention there were no statistically significant different responses received from boys and girls across all scales of the questionnaire: "what I think of school", "what I think of science at school", "I enjoy science experiments" and "I enjoy learning science content". Table 8.10 (appendix K, p.274) shows that boys' and girls' mean scores across all scales of "what I think of school science" were very similar (mostly in the high mean range). However, generally girls' mean scores tended to be higher than the boys (but not significantly so). Post-intervention there was only one statistically significant positive change regarding the scale: "I enjoy science experiments". The same positive change occurred for both boys and girls. Both showed a statistically significant change in enjoying "finding out for myself what happens in an experiment" (see appendix K, table

8.11). Post-intervention, boys had a lower mean score (statistically significant) in two questions in the science content area of living things "I enjoy learning about insects and mini-beasts" and "I enjoy learning about plants and how they grow". This did not happen for the girls.

As far back as 1975, Gardner, in his analysis of studies concerning attitudes to science, showed that in the majority of studies, boys had a greater curiosity for science than girls. He also showed that boys were somewhat more interested in physical science than girls. There is consensus among many researchers that boys are more inclined to have more positive attitudes to science than girls (Schibeci, 1984; Weinburgh, 1995;Osborne et al., 2003). Research by Woodwood and Woodwood (1998) into primary pupils' perceptions of school science showed that girls had a greater preference for biological science, while the reverse was true for physical science. A meta-analysis by Weinburgh 1995 covering the available literature on primary and secondary boys' and girls' attitudes to science (between 1970 and 1991) suggested that boys have more positive attitudes towards science than girls. Osborne et al. (2003, p.1062), writing about the UK, suggest possible explanations for such gender differences in attitudes to science, including the role of the teacher and the content of curricula being of far less interest to girls than boys. They also stress that this situation might be changing, mentioning that findings from new research in Britain shows that girl's confidence in school science is increasing.

The evidence from this study suggests that, post-intervention there is no difference between boys' and girls' attitudes towards school science, especially physical science. Living in this scientific world it is imperative that schools should do everything possible to encourage girls as well as boys to see the significance and relevance of science, especially physical science. As noted previously, deterioration in pupils' attitudes to science starts in primary school. An encouraging feature of this present study is that it shows that a targeted professional development programme (providing teachers with suitable content and teaching approaches) can enable all pupils (boys and girls) to enjoy science and develop positive attitudes towards school science.

8.3 Summary of salient issues

This section of the chapter is concerned with the two research questions mentioned in the introduction of this chapter. The first research question attempted to determine if the intervention programme brought about changes in pupils' attitudes towards school science. The answer to this question is a definitive yes. The reasons for this can be summarised as follows:

- The findings of this study have clearly shown that there was no deterioration in pupils' attitudes to school science during the two years of the project. In fact, there was an increase in the number of pupils who preferred science over other subjects found on the curriculum. This is a very important finding, especially when one considers that science is only one of twelve subjects that pupils have to learn in primary school. It is also a very encouraging finding in light of a recent European Commission report on science education *Science Education Now* (Rocard, 2007). Rocard reported that despite numerous projects and curriculum reforms in various countries there has not been a significant increase in young children's interest in school science.
- Post-intervention findings for the questions "You have to be clever to do science" and "Science is just too difficult" show that pupils perceive science to be less difficult. This is an important finding, especially when it comes to the uptake of science subjects at second level. If a pupil perceives the subject as being too difficult, this will affect their attitude to science in a negative way.

There are more than likely two key factors that have brought about these changes in pupils' attitudes to school science: (1) teachers are more confident and competent at science and as a result they present science at a level appropriate for their pupils, and (2) a change in teacher behaviour brings about a positive change in pupils' confidence and attitudes; i.e. pupils become more interested in science if they perceive that they are more confident with it. Pupils response to the open-ended question "what is your least favourite science lesson and why?" is further evidence that the intervention programme changed pupils' attitudes to school science in a positive way. Findings show that prior to their involvement in the project only 49 pupil respondents (17%) said they had no least favourite science lesson in school, post WSSP this increased to 79 pupil respondents (30%).

Research question two attempted to investigate the impact of the intervention programme on pupils' engagement and collaboration in hands-on activities. The findings summarised below show the intervention programme brought about significant positive changes in pupils' engagement and collaboration in hands-on activities:

- WSSP had a positive impact on the number of pupils engaging in hands-on activities in science classes. Findings to the open ended question “what is your favourite science lesson and why?” and the pupils’ drawings of themselves and their class doing science in school, revealed that pupils were carrying out substantially more hands-on open-ended investigations post-intervention. Prior to intervention 17% of pupil respondents wrote that their favourite science lesson involved them doing some hands-on activity. Post-intervention this increased to 28% of respondents. Pre-intervention the number of drawings showing pupils carrying out hands-on activities was 164 out of 281 pupils. Post-intervention this increased to 200 out of 261 pupils i.e. an increase of 22%. This is a very significant finding.
- Post-intervention findings show that there was a 50% increase in the number of pupils whose favourite science lesson involved the content strand unit “energy and forces”. The likely reason for this being that the teachers became more confident and competent in this topic area as a result of their involvement in the intervention programme. This concurs with research by Appleton and Kindt (1999) who reported that the natural reaction for teachers with low self-confidence in science is to avoid teaching the subject altogether or use various “avoidance stratagems”.

A number of research studies mentioned previously in this chapter reported that girls tended to have less positive attitudes towards school science than boys, especially in the physical sciences. The results of this study found no difference (post-intervention) in boys’ and girls’ attitudes towards school science.

The positive findings outlined in this chapter and the previous chapter provide substantial evidence to show that the intervention programme has brought about significant positive changes in pupils’ attitudes towards school science and teachers’ confidence and attitudes to teaching science. The next chapter provides a close-up study of teachers’ and pupils’ attitudes to school science (in three individual participating schools) over the two year period of the project, to discover whether or not the impact of the programme varies from one school to another.

Chapter 9

Looking More Closely at Three Individual Schools

Introduction

Chapters Seven and Eight have presented and analysed the research findings in an overall way. This chapter will narrow the focus into a micro study of three individual schools, to add depth to the findings of the study and indicate that within the main patterns of findings there can still be some contrasts. Detailed information about pupils' and teachers' attitudes to science in their classrooms over the two years of the programme is probed using data from the three schools by means of a combination of pre- and post-intervention questionnaires and group interviews. The chapter is divided into three main parts. The first part, (section 9.1) is concerned with responses of pupils in three schools to questionnaires and interviews pre- and post-intervention. Section 9.1 is divided into three sub-sections, including: experience of hands-on science in science class (9.1.1); experience of group work in science lessons (9.1.2); how and what pupils learnt in science lessons (9.1.3). Part two (section 9.2) examines the responses of the teachers in the three individual schools. It is sub-divided into: questionnaires (9.2.1); interviews (9.2.2); and reflection monitoring templates (9.2.3). The final part (section 9.3) provides a summary of the salient issues.

The three schools picked for the close study were strategically chosen: geographically - one school per cluster; and size – one with less than 50 pupils and two with between 50 and 100 pupils. The names of the schools used in this study are fictitious and are the names of three famous Irish scientists.

- Thomson – school with between 50 and 100 pupils, 15 miles from nearest town;
- Boyle – school with fewer than 50 pupils, 25 miles from the nearest town (very isolated);
- Walton – school with between 50 and 100 pupils, 5 miles from nearest town.

9.1 Findings from pupils in three individual schools

In this section of the chapter findings from the data gathered from pupils from each of the three individual schools are presented and analysed. The data come from pre- and post-intervention pupils' questionnaires and pupil group interviews, with a group of six pupils from each school (see DVD, audio 4 – 9 for pre- and post-intervention findings).

The purpose of the pupil interviews was to explore in more depth, pupils' attitudes and perceptions of their classroom experiences of science in their school, pre- and post-intervention implementation. During the interviews the pupils were asked a number of questions about what happens in their science lesson, (appendix E, p. 264). The researcher wanted to obtain information from the pupils regarding: the way they learned science in their science lesson, the features of school science that they liked and disliked, the kind of science they would like to do more of, and the science curriculum content areas they have experienced.

9.1.1 Hands-on activities

The intervention programme placed a very strong emphasis on encouraging teachers to carry out hands-on activities with pupils. At the WSSP workshops, teachers experienced hands-on activities from the pupils' point of view i.e. as if they themselves were pupils. They were encouraged to consider pupils' preconceptions when it comes to hands-on activities and to ask questions during the activities. An important aspect of the programme was to encourage teachers to carry out the hands-on activities they had experienced in the workshops, with their pupils back in the classroom and then reflect on this.

The pupils from the three close study schools were asked a number of questions such as, "do you like science in school?", "do you like doing experiments in science?" and "how often do you do experiments in science?" The main purpose of these questions was to get some insight into whether or not the pupils were carrying out hands-on activities in class, the types of activities, and how often they were carrying them out (pre- and post-intervention).

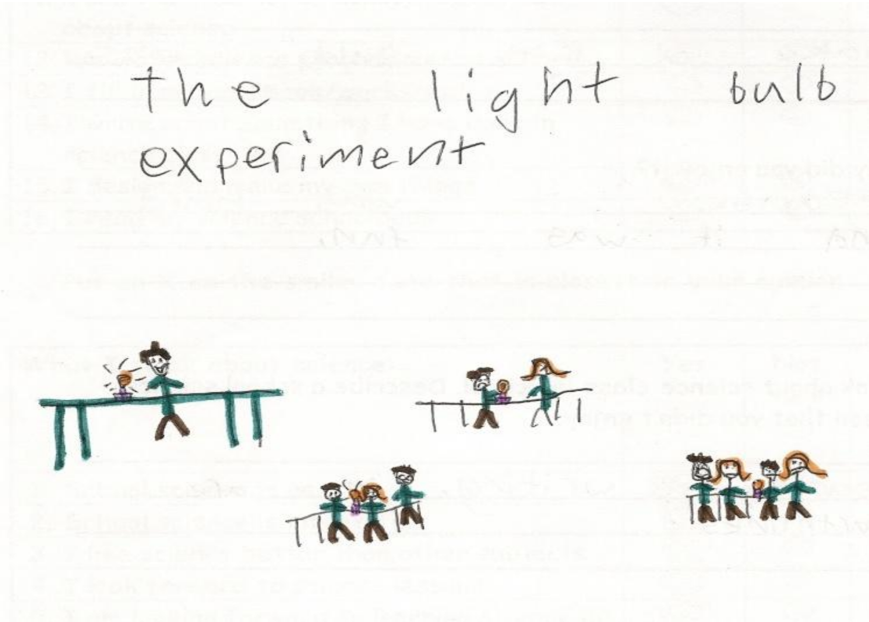
Thomson school

Thirteen pupils from Thompson school completed the questionnaires and six participated in the interviews. Before the intervention commenced, when asked during a group interview "do you like doing science in school?" Four of the six pupils stated that they did not enjoy science. Reasons given included: "last year we talked about science stuff, but we did not do any experiments", "we did a whole pile of reading from the book" and "I did not like science because we did not do any experiments". Only one of the six pupils interviewed said he liked science (pre-intervention), and the reason given was: "because you can do experiments, but we haven't done any experiments" (Audio

5, 0:00 – 2:36). At this early stage of the interview all six pupils said that they did not do any experiments in science class. However, at a later stage in the interview one of the pupils remembered doing an experiment in science. She stated "we did do an experiment last year; we made things float and sink". Post-intervention, when asked the same question three pupils said they enjoyed science. One stated "it's better than maths you get to do wires and stuff" according to another "I like doing experiments and stuff". When asked if they had done many experiments one pupil stated: "we have only done two experiments since the last time you were here...making bulbs light and making a volcano". The others agreed (Audio 8, 2:40 – 3:24).

Additional insights into pupils' hands-on experience in science lessons were gathered from analysing pupils' drawings of themselves and their class doing science in school, and from their responses to the open-ended questions regarding their most and least favourite science lesson. Pre-intervention, twelve of the thirteen pupils drew a picture of their class doing science. Three of these showed them carrying out hands-on activities (two making volcanoes and one floating and sinking); four showed them observing an experiment (three of these involved a volcano); five showed pupils sitting in their seats looking at the teacher in front of the class. Post-intervention, the number of drawings showing hands-on activities had increased to five children and the number of drawings with children observing experiments had decreased to three. Interestingly, the drawings were all concerned with only two topics found on the curriculum, electricity (making a bulb light) and materials (making a volcano), see figure 9.1 below. The drawings of the remaining four pupils showed them sitting in their individual seats looking up at the teacher who was showing them concept cartoons on the board. All the pupils interviewed pre- and post-intervention expressed positive comments towards participation in hands-on activities, all of them wanted to do more hands-on activities.

Figure 9.1: Child's drawing of science at school: children carrying out experiment on electricity (Post-intervention Thomson school)



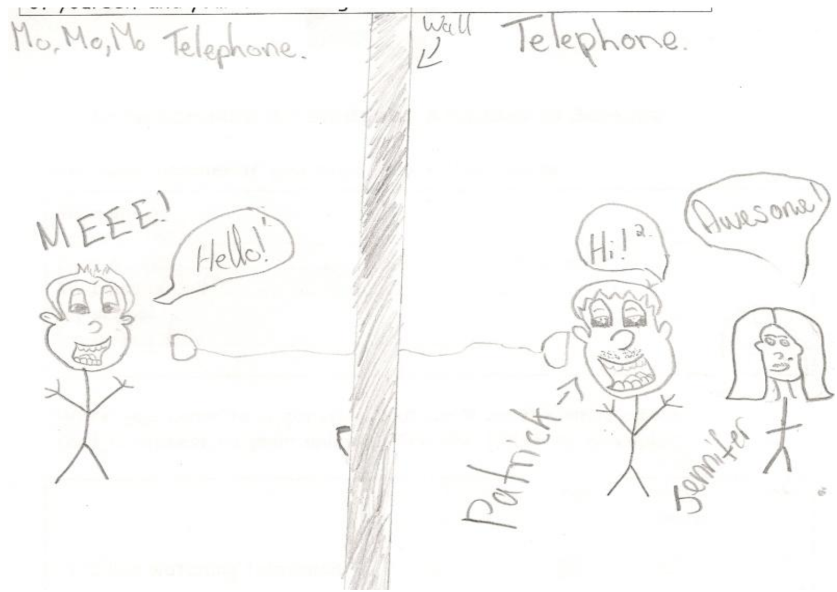
The children's response to the open ended questions also revealed similar findings. When asked about their favourite science lesson pre-intervention, three out of thirteen wrote about a lesson that involved a hands-on activity; the concept covered was floating and sinking (energy and forces). However, only one of the pupils interviewed mentioned this during the pre-intervention interview. This could suggest that the pupils have a limited memory, thus, when interviewed they could not recall doing hands-on activities. Or it could mean they had limited engagement in hands-on activities prior to the intervention programme. Post-intervention, the number of pupils who wrote, that their favourite science lesson involved hands-on science increased to ten pupils. Significantly, all ten wrote only about two types of activity: lighting the bulb and making a volcano.

Boyle school

Seven pupils from Boyle school completed the questionnaires and six participated in the interviews. During the pre-intervention group interview, when asked the question "do you like doing science in school?" all six pupils interviewed said "yes", they all gave the same reason i.e. they like to do experiments in science class. One pupil stated "I don't like writing but I like doing experiments" (Audio 6, 1:23 – 2:48). When asked what they did during science lessons, their comments included "we would write down stuff from the board...we would learn it off", one pupil stated "we would do a lot of sheets and write a lot, we would not do that many experiments" (Audio 6, 3:59 – 4:50). When asked the same question post-intervention, "do you like doing science?" all six pupils again replied that they were very positive and enthusiastic about science, one pupil commented: "we make a lot of stuff and grow things in the garden". When asked to expand on this statement the pupil commented that the class had made a lot of things in science such as: volcanoes, bridges made from paper and carrots, and they had grown vegetables in the garden. Other pupils commented on experiments they liked doing. These included: making string telephones, parachutes, nature walks and making electrical circuits (Audio 9, 0:18 – 1:42; 5:25 – 6:30).

Further insights into pupils' hands-on experience in science lessons were gleaned from their drawings of their science class and their responses to open-ended questions on the questionnaire describing their most and least favourite science lesson. Pre-intervention, all seven pupils drew a picture of their class doing science. Pictures drawn by four of the pupils showed them carrying out a hands-on activity, in all four drawings they were working with electrical circuits. The remaining three drawings showed pupils reading and writing. Post-intervention, all seven drawings showed the pupils carrying out a variety of hands-on activities (see figure 9.2). Activities included: gardening, making a string telephone, making a volcano, dissection of a fish.

Figure 9.2: Pupils drawing of science at school: children carrying out investigation on sound (Post-intervention Boyle school)



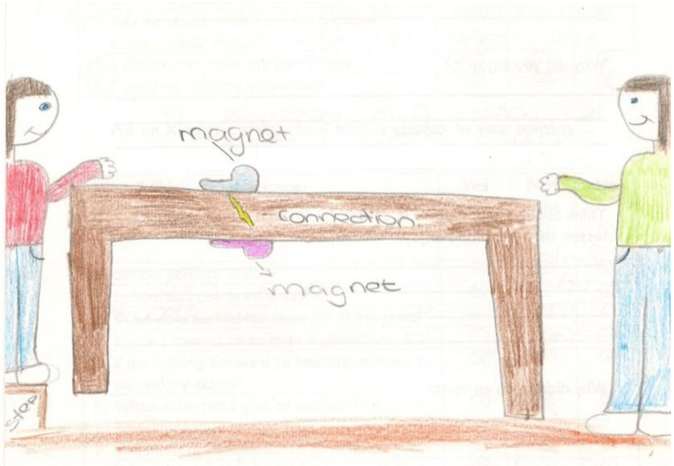
Pre-intervention, when asked to write about their favourite science lesson, all seven of them wrote about the "CSI" lesson. The "CSI" lesson was based on the Crime Scene Investigates detective series on television. The lesson was conducted by a visiting scientist and was hands-on in nature. Post-intervention, when asked about their favourite science lesson, all the participants described many different types of hands-on activities as their favourite science lesson. These included a variety of topics such as: magnets, electricity, gardening, making volcanoes, and forces and friction.

Walton school

Sixteen pupils from Walton school completed the questionnaires and six participated in the interviews. Pre-intervention, all six participants interviewed said they like doing science in school. Five of them stated they liked science because they "like do doing experiments". The remaining pupil said he liked science because "I like learning how the body works". When asked if they carry out many experiments, comments included: "we don't do science that much, we might read it from a book, but we don't do that much experiments" (Audio 4, 4:00 – 4:50). Post intervention, when asked what kinds of things they do in science, all six enthusiastically said "experiments". When asked about the types of experiments they did in science class, they talked about "making rockets...making traffic lights...making a rubber band guitar, and finding out the tighter it gets the higher the pitch" (Audio 7, 0:20 – 1:00; 4:04 – 4:34). Two pupils from Walton school mentioned the difference between the science they do now [post WSSP] compared to the last time the researcher interviewed them [pre WSSP]. These included: "there is more technology in the room now" and another stated "we do more experiments [now]" (Audio 7, 15:06 – 15:32).

As with the two previous schools, additional insights into pupils' hands-on experiences in Walton school were gleaned from the drawings of their science class and their responses to open-ended questions describing their most and least favourite science lesson. Pre-intervention, all sixteen pupils drew pictures of themselves and their class doing science. Five drawings showed them carrying out a hands-on activity and eight showed pupils observing experiments, four of these showed the teacher demonstrating an experiment. The remaining three drawings showed pupils reading text books while the teacher looked on. Post intervention the number of drawings showing pupils carrying out hands-on activities (figure 9.3) had increased to thirteen and the number showing pupils observing experiments decreased to three. None showed the teacher demonstrating experiments to the class.

Figure 9.3: Pupil's drawing of science at school: children carrying out an investigation into magnetism (Post-intervention Walton school)



Pre-intervention, when asked about their favourite science lesson, eight pupils wrote about carrying out experiments, three of these involved a hovercraft experiment, the other five wrote about making a wind gauge – this experiment is found on the geography curriculum. Post-intervention, all sixteen pupils wrote about hands-on activities when describing their favourite science lesson. Pupils described a variety of different activities they had engaged in including: making a game using magnets, making rockets, making volcanoes and making a rainbow using water and a prism.

These findings from the three individual schools clearly indicate that as a result of the intervention programme, pupils in these schools engaged in more hands-on activities. However, they also show that the impact of the programme, in terms of the extent of hands on activities varied from school to school. Possible reasons for such a variation in hands-on activities (post-intervention) are discussed in section 9.2. Close inspection of the findings clearly shows that post-intervention:

- Pupils in all three schools carried out more hands-on activities;
- Pupils in Thomson school engaged in a limited number of hands-on activities – only two were described by pupils;
- Pupils in two of the schools (Walton and Boyle) engaged in a greater number and wider variety of hands-on activities;

- Pupils from all three schools enjoyed hands-on experiences and would like to carry out more such science activities.

The evidence indicates that pupils from the three schools experienced more hands-on activities post-intervention. However, the findings did not reveal for certain whether hands-on activities were carried out on a regular basis in any of the three schools.

9.1.2 Group work

According to the NCCA (DES, 1999b) group work is an important method for organising teaching and learning. It allows "children have an opportunity to work together, share ideas and communicate their findings" (p. 52). WSSP encouraged teachers to organise their classrooms so their pupils could work together in groups. During the workshops participants worked together in small groups when introduced to new teaching approaches and hands-on exercises. Teachers were encouraged to try different methods of managing groups as outlined by the NCCA, such as, working in small groups, working on one activity, rotating around several activities (circus of activities), and working on open-ended investigations (DES, 1999b, p.52).

The pupils from the three close study schools were asked the question "have you ever worked in groups in science?" The main purpose of the question was to find out whether or not the pupils were working in groups during science lessons, when and how often they worked in groups (pre- and post-intervention).

Thomson School

During the pre-intervention group interview when asked the question "have you ever worked in groups in science?" All six pupils interviewed said "no". One pupil commented "we don't work in groups in any subject". All six pupils spoke favourably about working in groups even though they stated they had not experienced it. One commented "I would like to work in groups, because if you don't know something others can help you." Another mentioned "you learn more because there not as many people as there would be with the whole class" (Audio 5, 6:18 – 7:11). Post-intervention, when asked the same question "have you ever worked in groups in science?" four pupils replied "no" to this question. However one pupil stated "we now sometimes work in groups in science". When asked when does group work happen? He commented "when we do experiments" He also mentioned that they had only done two experiments in science (Audio 8, 10:53 – 11:36).

Boyle School

Pre-intervention, all six pupils answered “yes” to the question “have you ever worked in groups in science?” When asked the question “when do you work in groups in your science lesson?” They stated that it only occurred when they were doing experiments. All six pupils replied “yes” to the question “do you like working in groups?” Reasons given included: “it’s easier than working on your own because if you get stuck on one thing you can ask your friend” and “working in groups is better because there might be something that one person is better at than yourself, so they can help you” and “because it is easier doing science and more fun” (Audio 6, 5:20 – 5:30). Post-intervention, when asked the question “have you ever worked in groups in science?” all six pupils again said that sometimes they work in groups during science when they are doing experiments (Audio 9, 2:36 – 3:10).

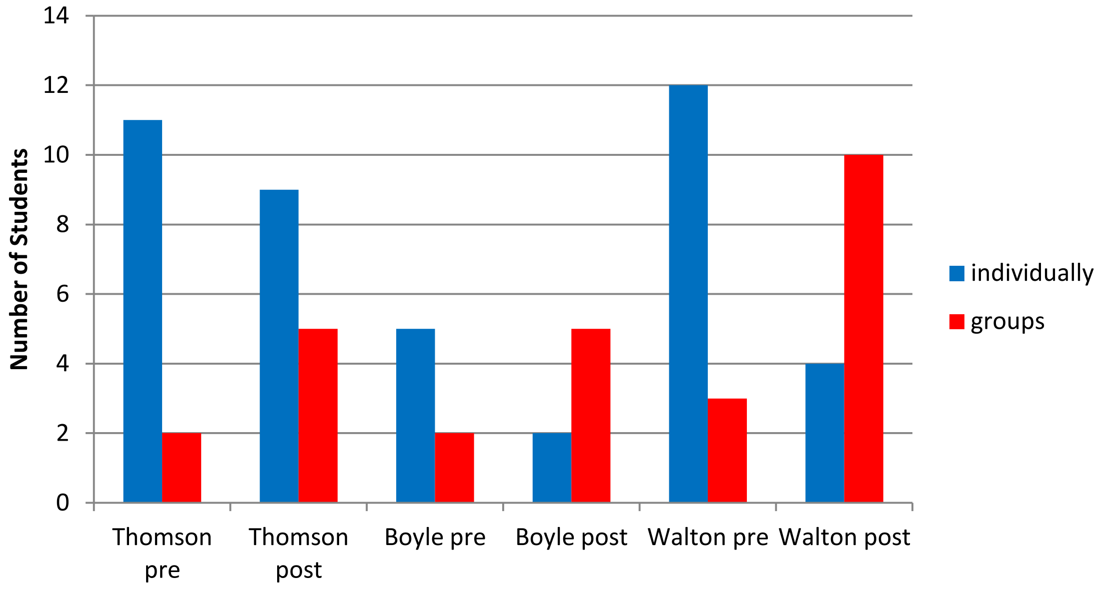
Walton School

Prior to the commencement of the intervention programme all six pupils interviewed answered “yes” to the question “have you ever worked in groups in science?” When asked “when do you work in groups in science lessons?” all six mentioned that group work is only carried out during experiments. Post-intervention, all six pupils gave the same response to this question; i.e. they always work in groups when doing experiments in science.

These findings from the individual schools indicate that the extent of group work carried out in each school still varied considerably. Further evidence regarding this variation is provided from analysis of pupils’ drawings, open responses and Likert items on pre- and post-intervention questionnaires.

All pupils in the three schools were asked to draw pictures of themselves and their class doing science at school. Their drawings were categorised into pupils working on their own and working in groups. Working in groups was taken to mean in pairs, small groups and whole class. The results are shown for each of the three individual schools in figure 9.4.

Figure 9.4: Pupils' drawings of themselves in science class carrying out experiments, categorised into working individually or in groups (before and after intervention)



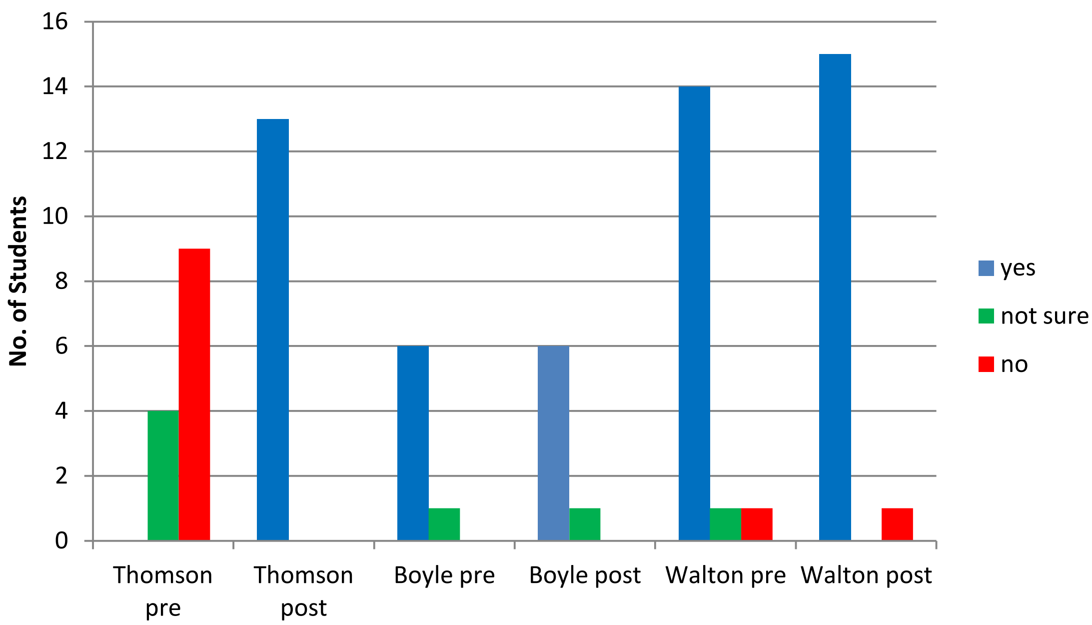
The results from figure 9.4 show that:

- In Thomson school prior to intervention two pupils (out of thirteen) drew pictures of themselves working in groups. Post-intervention this increased to five pupils;
- In Boyle school prior to intervention two pupils (out of seven) drew pictures of themselves working in groups. Post-intervention this increased to five pupils;
- In Walton school prior to intervention three pupils (out of sixteen) drew pictures of themselves working in groups. Post-intervention this increased to ten pupils.

Encouragingly, where pupils in all three schools were depicted working in groups with other pupils, they were predominantly engaged in hands-on work. These findings show that post-intervention more pupils in the three schools were working in groups. This is especially true for pupils in Walton school, where prior to intervention three (out of sixteen) drew pictures of themselves working in groups. Post-intervention this had increased to ten pupils.

Responses to the Likert question "did you enjoy doing science experiments with your friends?" provides further evidence that the impact of the intervention programme on pupils' attitudes regarding engaging in collaborative hands-on activities, varied from school to school. Figure 9.5 below shows the results of the responses of pupils in the three individual schools to the question, "did you enjoy doing science experiments with your friends?" Their responses were categorised into "yes", "not sure" and "no".

Figure 9.5: Pupils' responses to question "did you enjoy doing science experiments with your friends?" (pre- and post-intervention)



Post-intervention, there is a small increase in the number of pupils (1) in Walton school who like doing experiments in groups, there is no change in Boyle school. However, in Thomson school there is a massive increase in the number of pupils who enjoy doing science in groups. Prior to intervention, none of the pupils in Thomson school indicated that they had enjoyed science while working in groups. Post-intervention, all of them indicated that they enjoy it.

In summary these findings show:

- Pre-intervention, pupils in two of the schools (Boyle and Walton) engaged in group work in science lessons (only during hands-on activities), and pupils from Thomson did not engage in group work:
- Post-intervention, pupils from all three schools experienced group work in science lessons (only during hands-on activities);
- Pupils in the three schools expressed positive attitudes towards working in group's pre- and post-intervention.

As pupils in the three schools only experienced group work in science class when they engaged in hands-on activities, this implies (1) pupils in all three schools engaged in more group work post-intervention, and (2) post-intervention, pupils in Boyle school and Walton school experienced more group work than their counterparts in Thomson school. However, it is important to note that the findings did not indicate whether or not group work was happening on a regular basis, nor did they provide evidence of pupils engaging in group work in other aspects of science lessons that did not involve hands-on activities.

9.1.3 How and what pupils learnt in science lessons

The Primary School Science Curriculum: Teacher Guidelines (DES, 1999b) recommends that teachers should "use a variety of approaches and methods to facilitate the efficient implementation of the science curriculum" (p.53). Furthermore, they stress that the methodologies and approaches used by teachers should:

- Allow children the opportunity to find out things for themselves;
- Enable them to work on their own problems as far as possible;
- Encourage children to pose their own questions;
- Use children's ideas as the basis for activities.

(DES, 1999b, p. 53)

The project's workshops sought to introduce teachers to a variety of innovative methods and approaches to teaching and learning. Teachers were also encouraged to try these with their pupils in the classroom and to reflect on the effect they might have on the teaching and learning of science in their classrooms.

The NCCA Teacher Guidelines (DES, 1999b) places a strong emphasis on teaching a balanced range of topics from the four content strands: "the organisation of these strands is designed to ensure that the children experience a broad and balanced range of topics" (p. 7). The researcher was very conscious of this when researching the content for the various workshops. Even though the content of the workshops was shaped by the needs of the participants, the researcher encouraged them to try and place an equal emphasis on the four different content strand areas. The findings presented and analysed in this section suggest that the intervention programme had a decisive positive impact on how pupils learnt science in all three schools, namely, the use of more innovative teaching approaches, making science more interesting for pupils and developing a more positive attitude among pupils.

During the pre- and post-intervention interviews, pupils were asked a number of questions such as: “besides experiments, what do you like about science?” “What do you not like about science?”, “Can you describe a science lesson to me?” and “What would the teacher be doing during the science lesson?” The reason for this was to find out from the pupils how they learned science in school and the science topics they covered in their science lessons.

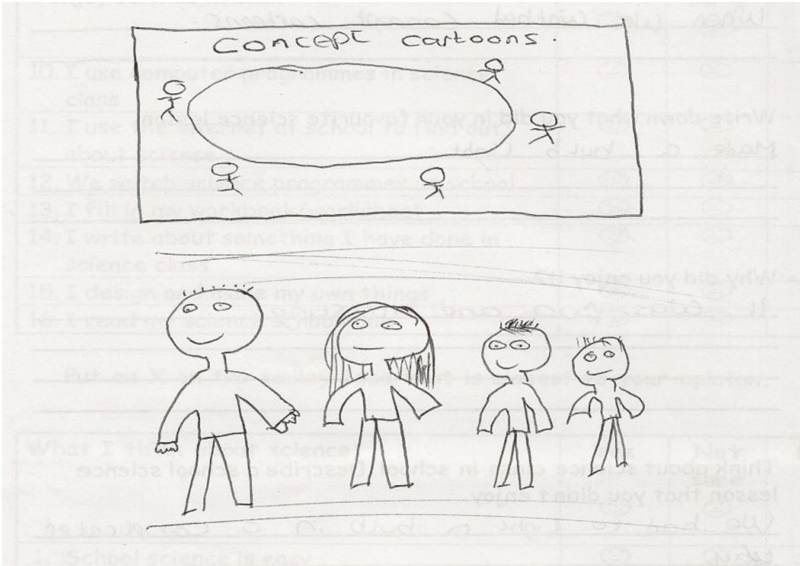
How pupils learnt science

Pre-intervention – The pre-intervention pupil interview data from the three schools indicated that some pupils felt that their science lessons involved them doing too much reading and writing and observing the teacher demonstrating experiments. These were typical features of the pupils’ recollections of their science classes. All the comments regarding reading and writing during science lessons were negatively expressed.

Thomson school

Pre-intervention, when asked the question “what do you do in science class?” two of the six pupils interviewed from Thomson school stated: “we do a whole pile of reading from the book” and “in the book there were chapters and experiments, we just read”. Three of them spoke about “doing a chapter from the *Earth Link* textbook”. One pupil commented: “we just read and write stuff from our Earth Link book”. Post-intervention, when asked the same question “what do you do in science class? One pupil commented that they mostly read in science class “we would be reading from the chapter”. Three other pupils agreed with him (Audio 8, 7:00 – 7:30). Another pupil spoke about “doing things from the book and writing them down”. However, four pupils spoke about their teacher using the interactive board, doing concept cartoons and having discussions in science class with them (figure 9.6). Comments included: “we do concept cartoons and have discussions about seeds and plants”, “we learn a lot from concept cartoons” and “when we did concept cartoons we learned about seeds and eggs” (Audio 8, 5:37 – 6:10; 14:10 – 15:20).

Figure 9.6: Pupils drawing of science at school: pupils carrying out concept cartoons (Post-intervention Thomson school)



Pupils' responses to open questions and their drawings of themselves in science class appear to corroborate the data obtained from the interviews. Pupils wrote about science lessons they did not like and why. Pre-intervention, seven out of thirteen pupils wrote that they did not like science lessons because they involved too much reading and writing. Examples included: "too much reading and writing...because it was boring and took ages"; "looking at stuff in books, it was boring"; "I didn't enjoy electricity because all you had to do was read". Post-intervention, five pupils wrote that they did not like science because there was too much reading and writing and four pupils wrote that they did not like doing concept cartoons in science. Written comments included: "some of the concept cartoons don't make a lot of sense", "concept cartoons are hard and complicated and boring."

Pre-intervention, drawings from five of the thirteen pupils show the teacher at the top of class with the pupils sitting in their individual seats either writing or reading. Post-intervention, drawings from five pupils showed the whole class observing the teacher using concept cartoons, and three drawings showed the whole class reading during the science lesson. These findings seem to indicate that the teacher placed a strong emphasis on reading and writing in science class both pre- and post-intervention. However, it also shows that as a result of his involvement in the intervention programme he had tried to implement a change in his classroom practice i.e. introduced concept cartoons methodology to his science lesson.

Boyle School

Pre-intervention, two of the six pupils interviewed from Boyle school expressed negative attitudes about doing too much writing in science class. When asked the question "what do you do in science class?" they instantly replied: "the teacher would write a lot on the board...and we would have to write it down"; "we would do a lot of sheets and write a lot" (Audio 6, 4:07 – 4:51). Other recollections made by pupils from Boyle school in the pre-intervention interviews showed that there was an over reliance on teacher demonstrations and teacher explanations on the part of their teacher. Pupils recalled (in a negative sense) that their teacher did a lot of talking in science. Examples of pupils' comments included "the teacher would do a lot of stuff on the board for us about science", "she would talk about stuff and we would have to learn it" (Audio 6, 4:11 – 4:57).

Post-intervention, when asked the question "do you like doing science?" five of the six pupils replied "yes." Reasons given included experiencing the following science topics: "volcanoes...electricity...gardening...reactions...sound...building stuff" (Audio 9, 0:10 – 1:41). When asked the question "what part of science lesson do you not like?" one pupil commented "I don't like science when you just talk or write things down." When asked to explain when this happens he stated "it usually occurs after we do experiments." All the others agreed with him (Audio 9, 2:07 – 2:23). There is some evidence of the teacher moving away from a prescriptive "recipe type" approach to hands-on activities to a more enquiry-based approach. When talking about carrying out experiments in science class (post-intervention) a pupil spoke about her teacher asking them to "gather equipment and predict what was going to happen in the experiment and then do it". She also commented "the teacher asked us questions about the experiment and ask us if we want help while we were doing it".

Pre-intervention, drawings from three pupils in Boyle school showed pupils sitting in their seats either writing or reading (as shown in figure 9.7). Drawings from the remaining four pupils show them engaging in hands-on activities. Post-intervention, drawings from all seven pupils showed them engaging in hands-on activities.

Figure 9.7: Pupil's drawing of science at school: (Pre-intervention Boyle school)

Findings from the pre-intervention questionnaires show that three of the seven pupils from Boyle school wrote that they did not like science because it was boring and involved too much reading and writing. Post-intervention, not one pupil wrote about science being boring and involving too much reading and writing as reasons for not liking science. In fact post-intervention, four pupils wrote that they did not like science. However, reasons given related to their hands-on experiences in science lessons. Reasons included: "there was a smell of vinegar on my hands when we made the volcano"; "the experiment was too easy"; "because we had to use our hands a lot"; "the whole room smelt of vinegar when we made the volcano".

Walton school

Pre-intervention, when asked the question "what do you not like about science?" three of the six pupils interviewed from Walton school stated that they did not like doing too much reading in science lessons. Comments included: "we don't do many experiments, we read it from the book"; "when we do science the teacher usually picks people to read and tells us to follow". Post-intervention, when asked "what do you not like about science?" two pupils mentioned writing. However, it was in relation to writing up experiments: "filling in sheets [worksheets] after we have done work [hands-on activities]"; "when you are having fun doing experiments teacher tells you to start writing down about the experiment".

Pre-intervention, only three out of sixteen pupils from Walton school wrote that they did not like science because it involved too much reading and writing. Post-intervention, not one pupil in Walton school wrote that they did not like doing science. In fact seven pupils wrote that science lessons were their favourite lessons. Pre-intervention, drawings from three pupils in Walton school show the teacher at the top of the class with the pupils sitting in their individual seats either writing or reading. Post-intervention, there were no drawings of pupils either reading or writing. All sixteen drawings showed the pupils engaging in hands-on activities. These findings indicate that the teacher from Walton school appreciated the importance of engaging her pupils in more hands-on activities.

To summarise, the pre-intervention findings from all three schools seem to indicate that pupils in two of the three schools (Thomson and Boyle) were taught by their teachers in a teacher-directed way i.e. the teachers in these schools placed a strong emphasis on the use of the textbook in science lessons as well as reading and writing. Pupils in two of the schools (Thomson and Boyle) appeared to have experienced teacher demonstration and teacher explanation as main aspects of their learning in science class. This concurs with the findings of Harlen and Holyrod (1997) who found that teachers with low confidence in teaching science use "coping strategies" to teach it. Such strategies include: over reliance on using prescriptive texts; minimal use of questions and discussion; only doing very simple practical work. Furthermore, they suggest that these strategies can have a negative impact on pupils' learning.

Post-intervention: – There is evidence to suggest that the three teachers from the different schools were trying out different teaching methodologies and approaches with their pupils in their classroom. The teachers from Boyle and Walton schools used a more hands-on approach to teaching science. The teacher from Thomson school, on the other hand, tried concept cartoons with his pupils. However, evidence (from pupil drawings and responses to open-ended questions) shows that he introduced concept cartoons in a teacher-directed way.

Science Content Topics

This section presents the data regarding the curriculum strands and specific science topics experienced by pupils in their science lessons before and after intervention. During the interviews the researcher encouraged the pupils to talk about science topics they had experienced in science class. Tables 9.1 and 9.2 show the topics that pupils (in the three different schools) spoke about having experienced during science lessons, pre- and post-intervention respectively.

Table 9.1: Pupil comments regarding topics covered in science (pre-intervention)

Curriculum Strand	Topic	Representative Examples of Pupils' Comments
Thomson school		
Living things	Human body	*We did teeth and the human body* *We were reading stuff about our bodies*
Energy & Forces	Electricity	*We learned that electricity goes through things*
	Forces	*We made things float and sink*
Boyle school		
Living things	Human body	*I learn new things about how body works*
Energy & Forces	Magnetism	*I like doing magnets*
	Electricity	*We done magnets and static electricity* *We did electricity and turning on light bulbs*
Walton school		
Living things	Human body	*I like learning how the body works* *We learned how food and liquid go through the body*
	Plants	*Teacher told us how leaves change colour*
Energy & Forces	Forces	*We had to cut strips of paper to make a helicopter* *We made things float and sink*

Table 9.2: Pupils' comments regarding topics covered in science (post-intervention)

Curriculum Strand	Topic	Representative Examples of Pupils' Comments
Thomson school		
Living things	Plants	*We went to the forest to look at trees*
	Animals	*We learned about seeds and eggs*
		We did stuff about bacteria
Materials	Materials/change	*We made a volcano*
Energy & Forces	Electricity	*We learned about how to make bulbs light*
	Forces	*We made things float and sink*
Boyle school		
Living things	Plants	*I like growing things in the garden*
Energy & Forces	Magnetism	*I like doing magnets*
		I don't like doing magnets
	Electricity	*I like doing stuff on electricity*
	Sound	*We learned about sound...we made a string telephone*
	Forces	*We made bridges out of paper*
Walton school		
Living things	Human body	*We learned about different parts of the body*
		Learned about weak spot in my eye
	Plants	*Learned about different parts of the flower*
		We planted flowers into our new garden
Energy & Forces	Forces	*We learned about how a boat floats*
		We make our own rockets and fired them outside
		We made our helicopter
	Light	*I did not like doing light no interesting facts*
	Sound	*We made a rubber band guitar...find out about pitch*
Materials	Materials & change	*I liked it when we made a volcano*

Findings from table 9.1 indicate that prior to WSSP pupils in the three schools recalled experiencing the science topics electricity, human body and forces in their science lessons. This is not surprising, as there was a strong emphasis placed on these strand areas during DES teacher in-service days (Varley et al., 2008, p. 23).

Post-intervention interview findings (see table 9.2) show that the pupils in all three schools recalled experiencing a wider variety of science topics. In addition to the topics already mentioned, pupils in Walton school also talked about engaging in topics such as: light, sound, gardening, different parts of the body, and forces (making rockets). Pupils from Boyle school spoke of topics such as: sound, floating and sinking, bacteria, trees and gardening. When the pupils spoke about these topics it was usually related to their hands-on experiences in science lessons. Pupils from Thomson school mentioned additional topics such as, plants and seeds, nature walks and bacteria.

Additional insights into pupils' engagement in the various science strands were gleaned from pupils' drawings of themselves during a science class. Table 9.3 shows the science topics included in pupils' drawings of themselves doing science in school (pre- and post-intervention in the three individual schools).

Table 9.3: Science topics included in pupils' drawings of themselves doing science in school (pre- and post-intervention)

	Pre-intervention		Post-intervention	
Curriculum Strand	Topic	No. pupils	Topic	No. pupils
Thomson school				
Energy & Forces	Electricity (light bulbs)	3	Electricity (light bulbs)	3
Materials	Volcanoes	4	Volcanoes	2
Boyle school				
Energy & Forces	Electricity	6	Electricity Sound	2 2
Materials	Volcanoes	1	Volcanoes	2
Living things			Garden	1
Walton school				
Energy & Forces	Wind (wind gauge) Electricity (circuits)	5 2	Electricity (circuits + static) Magnets Sound Forces (rockets) Gravity	3 3 1 2 1
Living things	Food (digestion)	2	Gardening	2
Materials	Volcanoes	2	Volcanoes	2

Findings from Table 9.3 show that pupils in two of the three schools (Boyle and Walton) experienced a wider variety of science topics post-intervention.

The findings obtained from the pre- and post-intervention pupil interviews and questionnaires (from three schools) only reveal what the pupils remember doing in their science lessons. It is more than likely that the teachers covered other science topics. However, for some reason, such topics were not experienced in a hands-on way, or the pupils did not recall and/or forgot to mention them. These results reveal that pupils in all three schools recall covering a wider variety of topics, post-intervention. They also seem to indicate that pupils in Walton school experienced the greatest variety of science topics post-intervention, whereas pupils in Thomson school experienced the least variety of topics post-intervention.

There is strong evidence from the previous chapter to show that the programme has had a positive impact on participating teachers' confidence in teaching science and this in turn had a significant effect on the way they taught science to their pupils. However, again it is clear from the findings that in the case of innovative teaching there was considerable variation between the three schools. As the teachers gained in confidence they tried out a variety of teaching approaches with their pupils and encouraged them to become independent learners, especially where hands-on activities were concerned. It is the researcher's considered view that variation among the three schools is probably due to some of the participating teachers becoming more confident and reflective when teaching science than others. There are various reasons for this and these will be investigated in the next section.

9.2 Findings from teachers in the three individual schools

In this section of the chapter, findings from the data gathered from teachers (one from each of the three schools) are presented and analysed. The data comes from pre- and post-intervention teachers' questionnaires, teacher group interviews, and monitoring templates.

9.2.1 Questionnaires

All three teachers have been teaching for more than 12 years, therefore, none of them received pre-service training in the revised science curriculum. The only professional development in science education they received prior to participating in WSSP was the two curriculum science in-service days provided by the DES. Two of the three teachers (from Thomson and Walton schools) had Leaving Certificate qualifications in biology; the third teacher (from Boyle school) had no qualification at all in science. Table 9.3 shows teachers' responses concerning their perceptions of their own capacities in the various aspects of science teaching (before and after intervention).

Table 9.4: Comparison between teachers' (in 3 schools) responses concerning their perceptions of their own capacities in the various aspects of science teaching (before and after intervention)

	Pre-intervention	Post-intervention
	individual score	**Individual score**
Thomson teacher		
How confident you are teaching science	4.0	5.0
How confident you are developing pupil scientific skills	3.7	3.8
How confident you are developing pupil design/make skills	4.3	4.3
How confident you are developing your own teaching skills	3.3	3.8
How confident you are teaching science content areas:		
Living things	4.3	4.3
Energy and forces	4.0	4.3
Materials	2.8	3.0
Environmental awareness	4.0	4.0
Boyle teacher		
How confident you are teaching science	2.0	4.0
How confident you are developing pupil scientific skills	3.3	3.3
How confident you are developing pupil design/make skills	2.0	3.3
How confident you are developing your own teaching skills	2.9	3.3
How confident you are teaching science content areas:		
Living things	4.5	5.0
Energy and forces	3.0	3.3
Materials	2.5	3.0
Environmental awareness	5.0	5.0
Walton teacher		
How confident you are teaching science	4.0	5.0
How confident you are developing pupil scientific skills	3.7	5.0
How confident you are developing pupil design/make skills	4.0	5.0
How confident you are developing your own teaching skills	4.5	4.5
How confident you are teaching science content areas:		
Living things	5.0	5.0
Energy and forces	2.8	4.1
Materials	3.0	3.0
Environmental awareness	5.0	5.0

The findings from table 9.4 clearly show that under most of the items, the three teachers made significant improvements in different aspects of their science teaching as a result of their involvement in the programme. However, they also indicate that improvements varied from teacher to teacher. For example post-intervention, the confidence score in teaching science for the teacher from Boyle school increased from a score of 2 (not confident) to a score of 4 (very confident). This compared to an increased score from 4 to 5 for the teachers in the two other schools. Close inspection of the findings across the five subscales regarding teachers perceptions of their own capacities in the various aspects of science teaching indicate: Boyle teacher increased by 9% points, Walton teacher by 12 % points and Thomson teacher by 6% points post-intervention.

9.2.2 Teacher Interviews

This section presents findings from the data obtained from contributions of the close up study of teachers from the cluster interviews (June 2010 – post-intervention). The main aim here was to find out the impact of WSSP on their classroom practice. Their responses are presented under the following headings:

- Confidence teaching science before and after attending the project;
- Changes in pupils' attitudes toward science since your participation in project;
- Introduction of new science strategies into your classroom.

*Confidence teaching science –*The teacher from Boyle school spoke about being more confident teaching science "I am more confident now [Post WSSP] I know what is happening in the science lesson" (Audio 3, 1:47 – 2:10). The teacher from Walton school talked about her growing confidence in her pedagogical skills, especially in the area of hands-on activities, "I am more open to doing hands-on work in the classroom I am moving away from the text... much more hands-on" (Audio 2, 10:32 – 10:54). The teacher from Thomson school commented that he now likes science whereas, prior to his involvement in WSSP he did not like science as a subject: "if you like a subject you will enjoy teaching it. I like science more now than at the start of the project. I am more confident teaching science now".

Pupil attitudes towards science – All three teachers told of how their pupils' attitudes towards school science had improved as a result of their involvement with WSSP. The teacher from Boyle school spoke of her pupils enjoying science since her participation in the project "they love it...they remind you of the subject every week" (Audio 3, 2:30 – 2:57). The teacher from the Walton school spoke of her improved self-confidence having a positive effect on her pupils' enjoyment of science. She stated, "the children now love science I think it is because I am more confident in teaching it. When you approach it confidently yourself it reflects on them to" (Audio 2, 8:06 – 8:16). The Thomson teacher commented "the children are requesting it [science] more often".

Science strategies – The three teachers spoke about using some of the innovative teaching strategies they had been introduced to in the workshops, with their pupils in class. Strategies discussed included concept cartoons, open-ended investigations, discussions and debates. Here are a few of the comments mentioned by the teachers.

> Concept cartoons are excellent; you can use them in so many ways. I have only used them with children working on their own. They create so much debate. (Thomson teacher) (Audio 1, 0:50 – 1:14)

> Open ended investigations are a great innovation in my classroom before them science was clear cut and dried. We knew what was going to happen before the end of the lesson. With open ended tasks pupils really get into them, enjoy debating possibilities and predicting outcomes. Kids get a lot more out of it concepts wise. I would not have been as confident in engaging in that prior to WSSP (Walton teacher) (Audio 2, 0:23 – 1:10).

> I have moved away from the books and used the ideas you [researcher] have shown us, and spread over three or four weeks I found that very beneficial (Boyle teacher) (Audio 3, 1:09 – 1:22).

9.2.3 Reflection monitoring template

This section presents findings from the open-ended reflection monitoring template received from the three case study teachers at end of Year One (June 2009). Evidence from the reflection templates seems to corroborate the data obtained from the teacher interviews. Their responses are presented under the following headings:

- Confidence teaching science before and after attending the project;
- Introduction of new science strategies into your classroom;
- Changes in pupils' attitudes toward science since teacher participation in project.

Confidence teaching science – all three teachers wrote about the project helping them to increase their subject knowledge and develop a wider variety of pedagogical skills. Examples include "my own knowledge of science has been broadened" (Thomson teacher), "my knowledge has increased, I am more confident to try out new things and doing more hands-on activities" (Walton teacher), and "I am much more motivated now, I try new ideas" (Boyle teacher).

Change in teaching approach to science – two of the three teachers (Walton and Boyle) wrote about how their involvement in the project encouraged them to change their approach to teaching science. Moving away from a teacher-centred approach to teaching to a more pupil-centred approach to teaching: “I don’t have to know all the answers anymore. I used to avoid areas that I didn’t have the answer. I now give over more time for discussion” (Boyle teacher) and “when doing experiments now I ask them about their ideas regarding the purpose of the experiment and get their ideas about it” (Walton teacher). The teacher from Thomson school wrote about being more relaxed now teaching science as a result of having broadened his science knowledge base: “I am more relaxed about my knowledge of science, it has increased quite a bit”.

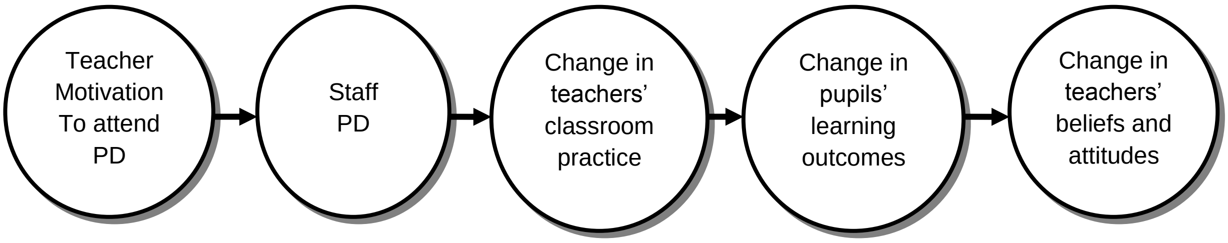
Changes in pupil attitudes towards school science – Comments from two of the teachers (Walton and Boyle) indicated that the project had had a positive impact on their pupils’ attitudes towards school science: “the project has led to a lot more pupil questioning, discussion, and hands-on science” (Walton teacher), “the pupils are questioning everything, they have a new focus and interest in science, they want to know what topic is next. They are actually thinking more about science” (Boyle teacher). Closer scrutiny of these comments indicates that pupils’ positive attitudes towards school science are closely related to the teachers’ approach to teaching science – encouraging their pupils to question and think. The teacher from Thomson school wrote about his pupils now having a more broadened view of science and the school having more science resources as a result of their participation in the project. He wrote “we now have a science trolley full of equipment and we get visits from scientists” and “their [pupils’] view of science has been broadened this year”. However, he did not write about a change in pupils’ attitudes to school science, or their experiences of using hands-on activities in his own science class.

9.3 Review of salient issues

The findings from these three teachers clearly show the level of engagement in WSSP varied from teacher to teacher and some teachers made more progress than others. They also show that the level of engagement in the project impacted on pupils’ attitudes to science. For example, the teachers from Walton and Boyle schools became more confident teaching science, especially hands-on science (post-intervention). Both teachers actively participated in the WSSP workshops, constantly asking questions regarding science content and pedagogical skills. They also applied new ideas and teaching methodologies in their classrooms and provided "critical" reflection and feedback to workshop colleagues regarding the impact of these methodologies (positive and negative). Their pupils' positive responses and enthusiasm to hands-on activities encouraged both teachers' confidence and desire to continue with the new strategies. These findings support Guskey's (1986) argument that, it is when teachers try out new ideas in their class and gain evidence of positive change that a change may occur in their beliefs. These two teachers were consciously trying to move away from a "deductive" teaching approach to a more "inductive" approach in their science lessons. The two of them also invited the researcher into their respective schools to observe them teaching science and to teach science to their pupils. As a result of the project, these two teachers became more reflective about what they teach and how they teach science. The teacher from Thomson school did not implement many of the new innovative teaching strategies, including the wider use of hands-on activities (post-intervention). Evidence shows that he only made slight changes to his teaching and classroom practices and this provided only minor positive results in both pupils' attitudes and motivation towards school science. When he introduced a new innovative approach (concept cartoons) to his pupils he appeared to teach it in a "deductive" manner (findings from pupil interviews and drawings show him standing in front of the class asking them questions). This could be the reason why a number of his pupils stated that they did not enjoy using concept cartoons. At the workshops he appeared to have basic science knowledge and skills and seemed to enjoy the social and intellectual stimulation. However, only once at a workshop did he "critically" reflect on the impact of a new teaching methodology (concept cartoons), that he had used with his pupils in his own science class. It seems that he was not motivated to utilise many of these new strategies in his own classroom. For example, pupil findings (interviews and questionnaires) seem to indicate that the teacher from Thomson school avoided doing hands-on activities.

It is more than likely that such a variation in teacher engagement occurred across the other twelve schools participating in the project. Such variations can be explained by a number of factors such as: school culture, lack of time, personal issues and personal expectations. The motivation of teachers to take part in professional development is also an important consideration. It was assumed by the researcher that the professional development utilised in this study would motivate and lead to a positive change in teacher classroom practice. Self-motivation can influence how well the information and concepts from the workshops are understood, internalised and realised. It is the researcher's considered view that a teachers' motivation to attend professional development programmes is a very important impetus to teachers changing their classroom practice. In fact it could be added as an initial step to Guskey's model of teacher change as shown in figure 9.8 below.

Figure 9.8: Adaptation of Guskey's model of the process of teacher change



As stated in Chapter One the participating schools were picked by the DES on behalf of the IAP. In the initial contact between schools and the DES, principals were informed that their school would receive resources and funding as an incentive for taking part in the project. The schools received most of this funding before the researcher had his first meeting with the teachers. When the researcher first met with the participants he encountered a wide variety of reasons regarding what had motivated them to participate in the project. Some teachers were very enthusiastic and were looking forward to help with improving their school science. However, others seemed less keen; they wanted to know if it would take up much time? and would they have to do extra work? Three of them said they were at the workshops because their principal had asked them to attend. Such variations indicate that the project was not dealing with a *level playing field* when it came to their commitment and involvement with WSSP. Such variation meant that different teachers engaged in the project at different levels. For instance there were the highly motivated teachers who worked very well at the workshops, tried a variety of new teaching strategies with their pupils and reflected on the teaching and learning that took place in their classroom. Other teachers made very positive contributions to the workshops, however, for various reasons their commitment between workshops was "patchy". Two teachers spoke to the researcher regarding the lack of commitment and in some cases apathy and resistance from their teaching colleagues in their own schools to the ideas and approaches they picked up at the workshops.

Jarvis and Pell (2004) carried out a major science in-service programme with primary school teachers in the UK. They examined teachers' confidence and attitudes towards science teaching and their knowledge of science both before and after the implementation of the programme. They reported that "after in-service teachers' confidence about science teaching had improved significantly. The majority but not all, had developed satisfactory levels of understanding and more positive attitudes" (p. 1787). Jarvis and Pell argued that the teachers responded to the in-service programme in different ways.

They identified four teacher types (p. 1800):

- Unaffected teachers – started with above average cognitive performance and average attitudes, the in-service programme had little affect;
- Disaffected teachers – had low cognition, competence and confidence throughout the programme;
- Enthusiastically fired teachers – improved attitudes and confidence during the in-service;
- Limited science knowledge teachers – found the in-service programme difficult but made improvements.

Jarvis and Pell demonstrated a link between the types of teacher and the rate of development of pupils' understanding of science, as well as pupils' attitudes towards science. They also stressed that teacher types have implications for the design of in-service programmes. These two issues: what motivates teachers to participate in professional development programmes; and "teacher types" deserve closer attention in any future research work in this area. It is important to stress that all three teachers and their pupils in the close study benefitted from their involvement in the project.

Chapter 10
Review of Three Key Interlinked Strategies

Introduction

The data presented in Chapters Seven, Eight and Nine are very specific to the project. There are a number of issues that arise in this chapter that are of a wider concern and are touched on through two aims of the thesis, namely: (1) breaking down the professional insulation and isolation that teachers experience in their day-to-day professional lives and (2) the building up of a professional learning community between the participating schools. This chapter attempts to track and appraise the journey which the fifteen primary schools and their participant teachers made over the two years of the project. It focuses specifically on the two aims mentioned above, and provides a commentary on the issues arising.

The chapter is divided into three parts. The first part (section 10.1) investigates the importance of meaningful collaboration in breaking down teacher insulation and isolation. It argues that for professional development to bring about significant change in teachers' practice there is a need for trust and collaborative relationships to be developed between participants, and also between participants and the facilitator. It also outlines the important role of the facilitator during the programme. The second part (section 10.2) explores how the participatory and collaborative nature of the project enhanced teachers' capacities to critically reflect on their classroom practice. The third part (section 10.3) considers the importance of teacher networks, especially virtual learning environments and informal teacher networks, in creating professional learning communities. Within each section the researcher identifies a number of factors that challenged the successful implementation of the WSSP programme and the strategies used to overcome these.

10.1 Meaningful collaboration

According to Hogan et al. (2005 p. 5) the insulation and isolation of teachers from their professional colleagues has been one of the more enduring factors in Irish schools. Breaking this down and building up a professional learning community posed a major challenge during the early stage of the WSSP project. The majority of the participating teachers taught in small 2/3 teacher schools. From the researcher's initial meetings with teachers in his role as facilitator, it was clear that there was little or no formal discussions with colleagues within their own schools on matters related to teaching and learning. In fact, three of the teachers were of the mind-set that what happens in the privacy one's own classroom was not up for discussion with colleagues. For example, one participant stated "the only time another teacher was in my classroom while I was teaching, was my inspector during my teacher training days". In order to introduce the participants to new innovative initiatives, the researcher encouraged them to gradually de-privatise their classroom practice.

Building up trust over time was the key to developing a culture of meaningful collaboration. It was important to realise that participation in WSSP involved an element of risk-taking on the part of teachers. For the majority of participating teachers, openly discussing their own and other teachers' classroom practice is something they have not done since their teacher training days. Building up trust involved a number of strategies, including:

1. The researcher working closely with teachers in a very supportive way;
2. Looking at real issues and needs of teachers in the day-to-day reality of their classrooms and most importantly, dealing with these issues, not just glossing over them;
3. Involving teachers in decision making processes. It was important that issues raised by the teachers themselves were seriously examined, probed and decided upon in a collaborative way;
4. Encouraging teachers to reflect critically on their classroom practice and that of their colleagues.

Callan (2006), writing about the role of in-service support teams maintains, "the current practice where in-service support personnel visit schools and focus solely on 'their course' or 'their subject' is difficult to justify. The difficulty with this approach is that single innovation projects tend to ignore the interconnected conditions that influence classroom practices" (p. 222). Prior to the implementation of the project the researcher visited all the participating schools (meeting teachers and principals). This enabled him to familiarise himself with any concerns or issues they might have. Most importantly, it gave him the opportunity to establish a collegial relationship with the teachers, one where they were valued as professionals. Listening to the concerns and needs of the teachers was an important aspect of developing a close and trusting relationship between the researcher [facilitator] and the teachers.

A central feature of the project was a respect for the participants' intellectual thoughts and ideas. It was important for the teachers to believe that their ideas would be considered valuable and of interest to others. In addition, it was important that they felt they were not being judged, or told of their weaknesses by the outside "expert". These initial visits were followed up with a number of subsequent visits by the researcher (when requested). Through these visits the researcher became known in the schools and was perceived as a credible person who understood the issues confronting teachers at school level when looking to develop new practices (Callan, 2006, p. 174). In addition to these school visits, the researcher was in constant contact with the participants through the virtual learning environment (Moodle), e-mail and telephone. The purpose of this was to act as a support and stimulus for the participants when they were carrying out innovative teaching methodologies in their classrooms.

Issues and concerns that were raised by teachers during the researchers' initial school visits were discussed and dealt with in the workshops. These were seriously examined in an open-minded, non-coercive way. This building up of trust in a collaborative way would not have been achieved if the researcher had totally controlled the direction of the workshop and did not consider the individual needs of the participants.

Role of the Facilitator

Just as the teacher is the key to implementing change and reform in the classroom, so it is that the facilitator is central to the success of a professional development programme. The role of the facilitator is not just confined to the delivery of professional development workshops. In essence, the facilitator of WSSP had two main roles: (1) liaising with and supporting teachers in their schools in-between workshops, and (2) facilitating content-based workshops at cluster level. The importance of first role has already been explored in the previous section. Regarding the second role, there are numerous skills that a facilitator needs, to contribute to the effectiveness of a professional development programme, as the experience of the project repeatedly bore out. These include: being well organised, confident and competent in the subject area, possessing good interpersonal skills and insights, as well as having a high degree of sensitivity and empathy. The comments below (interviews and monitoring templates) show that there was a substantial degree of trust in the facilitator and that good relationships developed between the facilitator and the participants, and among the participants themselves. These teachers' comments are indicative of teachers in the three cluster groups.

> The help you get between workshops was a brilliant part of it [project]. If it did not work out for you [in class] we could discuss this at the next workshop or contact you [researcher].
>
> Discussions with the facilitator and other teachers stimulated a further interest in teaching science.
>
> The backup and support of the facilitator for the teaching of science was invaluable.
>
> I really enjoyed the interaction with the other teachers and of course, the facilitator.
>
> The facilitator lets us explore our own thoughts and ideas while directing us in a positive way.

The gradual development of trust and collegial relationships between the facilitator and teachers and among teachers was an influential factor in the successful implementation of the WSSP programme. This may have implications for designers of future professional development programmes.

10.2 Cultivating reflective practice

A very important feature of WSSP involved helping teachers to develop their capacities to critically reflect on their teaching practice, with a view to bringing about change in their classroom practice. The workshops afforded teachers the opportunities and time to encourage reflection in a supportive environment. Such opportunities concentrated on key issues and happenings in the teachers' experiences of teaching science and relating these to important insights from the research literature associated with teaching practice. Teachers were encouraged to: question the quality and nature of the learning that takes place in their classroom, examine the relationship between the teacher and pupils and, investigate new ways of bringing pupils more centre stage within the learning process. Examples included: selection of content, teaching approaches used, learning theories, classroom management and selection and uses of various resources. Despite some initial reticence among approximately a third of the participating teachers, all of them came to embrace the opportunities for reviewing in a collaborative way the shortcomings as well as the strengths in their own teaching.

Confirmation of the development of self-reflection and group reflection is evident from the following comments which were made by teachers during interviews and written reflections. These teachers' comments are representative of teachers in the three cluster groups.

> Sharing your own ideas and bringing back other people's ideas to school is very important.
>
> It was great to talk and listen to other people regarding science teaching; you learn so much.
>
> It is very important to talk to other teachers who are teaching the same age group of children as yourself; you can share ideas and resources.
>
> Sharing and helping each other, others have the same problems, having open discussions at workshops is very important.
>
> I try out new ideas I picked up at the workshops with my class, think about the best way to teach it. I will ask for help if I need it.
>
> Great to try out what we learned in a workshop with our pupils and then discuss how it went with the other teachers at the next workshop.

This is a very encouraging finding however, it is important to point out that it was not until the later part of the project (start of Year Two) that the teachers fruitfully developed their capacity for self-reflection and group reflection. This is very understandable given that for many of the participating teachers in WSSP were not accustomed to sitting around a table discussing any part of their pedagogical practice. Time is an important factor in the successful implementation of change. The on-going nature of WSSP gave the participating teachers' time to reflect on their teaching and instigate changes in their classroom practice.

10.3 Promoting teacher networks

The WSSP programme has promoted and supported the creation of two teacher networks, one formal and one informal. The formal network evolved during workshop time i.e. scheduled activities. The informal network happened outside the programmes regularly arranged activities and was initiated by a significant number of teachers.

Formal Networks

During the workshops networking with colleagues offered the participants different learning experiences that they could not obtain from expert-led activities. As well as swapping materials and exchanging ideas teachers worked, talked and shared their expertise on issues of teaching and learning, with their fellow teachers. This started the growth of a peer based support system. For example, at the workshops (especially in Year Two of the project) participants were encouraged to work together in groups of two or three when investigating innovative teaching methodologies and hands-on activities. Each group was then asked to report back to the main group on the benefits and challenges of introducing their pupils to such methodologies. Between workshops a significant number of group members would implement aspects of the methodologies with their pupils. On numerous occasions they would also contact other group members to give and receive advice on their experience. At the next workshop they would give feedback to their colleagues and the researcher. The groups were organised on a rotation basis. Much of the success of this support system was due to the fact that the participants shared their *true* science lesson experiences with colleagues, difficulties as well as successes. Collaboration and collegiality along these lines becomes part of one's professional identity and therefore works to generate more valuable adjustments in teacher's practice (Malone & Smith, 2010, p. 111). Unfortunately due to circumstances outside the researcher's control, it was not possible to bring all three cluster groups together (face-to-face) on any occasion. Such a drawing together would have deepened collaboration and communication across the three clusters.

Informal Networks

In addition to the formal networks that arose in the collaborative workshops, the teachers established their own informal networks within and between the three clusters of schools. Informal networking mainly involved teachers sharing resources and teaching ideas It occurred through face-to-face contact, telephone calls, e-mail and virtual learning environments.

Some professional development programmes have included various technology-related parts, such as: web-based virtual learning environments, online and electronic conferencing features. An important aspect of such technology is that it can overcome location and time constraints. The TL21 Project (Hogan et al., 2007) provides a good example of the use of a virtual learning environment (Moodle) in an Irish professional development context. Moodle allowed teachers in that project to contact each other through a university-based secure web network, enabling them to actively upload and download digital resources, share information and, most importantly, engage in sophisticated conversations around their pedagogical practices (successes and difficulties). The participants came to see such practices as an integral feature of their professional identity, as opposed to something which was merely an add-on (Malone & Smith, 2010, p. 112). Many of the teachers overwhelmingly expressed their desire to keep in contact with each other when the TL21 project finished. They asked the project team to maintain Moodle – so that this could be achieved (Hogan et al., 2007). A small group of participants (15) remained in contact with each other post TL21. However, without the services of a convenor or co-ordinator, use of Moodle became sporadic and participants eventually lost contact with each other.

At the start of the WSSP intervention programme, the participating teachers were set up on their own virtual learning environment (Moodle) and trained to use it. The project faced a number of challenges/obstacles regarding the implementation of Moodle, including: (1) A large number of teachers lacked confidence in ICT and were initially slow to use Moodle. It was not until the start of Year Two of the project that teachers felt confident and comfortable uploading and downloading resources. (2) In a number of schools the broadband connection was a problem; on numerous occasions it would be very slow and/or breakdown. (3) A number of workshops which involved the use of broadband had to be transferred from a school venue to one that had Wi-Fi (usually a hotel) and (4) Teachers did not get a chance to engage in on-line conversations around pedagogical practice.

Teachers who previously did not know one another were now in touch with each other professionally (telephone, e-mail) seeking clarification on ideas and tasks exchanged at workshops, they also shared ideas and resources. The following three examples illustrate this:

1. The K’NEX Challenge is an initiative run by Engineering Ireland; it provides primary school children with an introduction to the world of engineering and design. The pupils taking part in the K'NEX Challenge work in teams to design and build a model (e.g. a fire brigade or crane) using K'NEX kits. Prior to their involvement in WSSP, the schools took part in the K'NEX Challenge on an individual basis. This entailed a lot of organisation on the part of the individual

schools and the K'NEX Challenge team. However, since their involvement in WSSP, schools within each cluster now work collaboratively in organising and carrying out the Challenge. They now use a local Community Centre, invite in Engineering Ireland and all five schools in each cluster take part in the Challenge together.

2. Schools within and between clusters have also co-ordinated science trips and science related visits for their pupils. The following two examples illustrate this. (a) All five schools in one cluster organised a trip to the W5 (interactive – hands-on) Science Museum in Belfast. This allowed for a greater social interaction between teachers and pupils from the different schools and a reduced cost. (b) A teacher from one school wanted to bring Astronomy Ireland and its mobile planetarium to visit her pupils. She contacted the teachers in the other schools in her cluster. This teacher also posted details of the proposed visit on Moodle. Teachers from schools in all three clusters then contacted her and organised for Astronomy Ireland to visit their schools also (thus cutting down on the cost).

3. Teachers and pupils across all three clusters carried out a number of science projects in their schools and exchanged their findings (via the internet) with teachers and pupils in other schools within and across the other clusters. An example of this was the "Eating and Drinking" project. This focused on nutrition and the links between diet and health. Pupils reflected on the cultural significance of diet and exchanged information about food and health with pupils from schools in the other clusters. After exchanging their findings and views pupils compared and discussed the responses they had received from the pupils in the other schools.

The formal and informal teacher networks discussed above represent a flexible and accessible way for teachers to engage in professional development and to exchange knowledge on pedagogy and curricular content. Developing such networks required a significant amount of time and trust. The networks helped the participants deal with the real and actual concerns and issues they faced in their classrooms (de-privatising their classroom practice). They also encouraged professional socialization and collaboration.

According to McLaughlin and Talbert (1993) involving teachers in a community of like-minded peers, giving them the opportunity to learn from each other, has a powerful effect on their work in the classroom. WSSP has gone a long way to developing such a professional community. This was achieved by the participating teachers progressively learning from their peers as they shared ideas and experiences of their teaching practice.

Looking ahead, the concern for the researcher is whether or not these participants will continue to reflect on teaching and learning issues in their classroom. Once the project is finished the above mentioned challenges may not allow for maintaining the impetus gained by the participants of the programme. Those involved in planning professional development programmes need to give consideration to the longer-term processes of change, changing teachers role in schools and the need for a clustering model of professional development (especially for teachers in small rural schools). This is discussed in detail in the final chapter.

Chapter 11

Summary, Implications and Recommendations

Introduction

This chapter reviews, in summary some the main themes that have emerged from this study. The first part of the chapter (section 11.1) presents a synopsis of the key findings in terms of seven research questions. This is followed by a discussion of the factors that contributed to the successful implementation of the WSSP model of professional development and of the implications of the findings of this study for the professional development of Irish primary teachers in science (section 11.2). The limitations of this study, recommendations for designing and implementing future effective CPD, and avenues of further study are presented successively (section 11.3; section 11.4 and section 11.5). The final part of the chapter (section 11.6) concludes with an overview of the study.

11.1 Synopsis of the findings

The main aim of this study was to develop a model of professional development in science education with primary teachers in 15 small rural schools, in order to enhance the teaching and learning of primary science in those schools. The following synopsis brings together evidence from the teacher and pupil questionnaires and interviews in terms of the seven research questions which guided this study:

- What changes in teachers' confidence in teaching science and competence in relation of knowledge of the science curriculum occurred during the study?
- What changes in teachers' attitudes to teaching science occurred during the study?
- What changes in teachers' classroom practice occurred during the study?
- What changes in pupils' attitudes towards school science occurred during the study?
- What changes in pupils' engagement and collaboration in hands-on science activities occurred during this study?
- What aspects of the intervention programme promoted or inhibited teachers' subject confidence, competence and attitudes?

- What aspects if any of the model influenced the development of 'learning communities'?

RQ1: *What changes in teachers' confidence in teaching science and competence in relation to knowledge of the science curriculum occurred during the study?*

As mentioned in Chapter Four (section 4.5.1), having good subject knowledge is key to enabling teachers to develop effective teaching (Osborne & Simon, 1996). Low confidence levels in science have a negative impact on teaching. Harlen and Holyrod (1997) argue that teachers with low confidence and understanding are likely to have a poor self-image as a teacher of science and teach as little of the subject as they can get away with (p. 103). Findings from Chapter Seven show that prior to their participation in the WSSP programme, a lack of confidence and understanding of science concepts was prevalent among the participants. These results support the research findings discussed in Chapter Five that suggest that primary teachers for the most part have not been adequately prepared to teach primary science effectively. The results of the questionnaires and interviews at the end of the intervention programme indicated that teachers' involvement in the programme helped them to extend their knowledge of science content and increase their confidence in teaching primary science. The participating teachers attributed their improved teaching practices and new science knowledge, chiefly to attendance at workshops provided by the WSSP programme. These results are consistent with the work of Harlen (1997), which shows that increasing teachers' own understanding is a key factor to improving the quality of teaching and learning science. Despite the fact that WSSP was very successful in increasing teachers' confidence about primary science, a small number of the participants still maintained a number of misconceptions regarding various scientific concepts. This is an indication that teachers, like pupils, come to professional learning situations with different backgrounds and experience in subject areas, and if they are to change they will need more time and support.

RQ2: *What changes in teachers' attitudes to teaching science occurred during the study?*

International research (Rennie et al., 1985; Simpson & Oliver, 1990; Tobin et al., 1994) has shown that teachers' attitudes towards science have a critical influence on whether their pupils develop positive or negative attitudes towards science. The WSSP programme was effective in changing teachers' attitudes to and motivation towards science in a positive sense. As already mentioned in RQ1, teachers indicated that participation in the project raised their confidence to teach science. Consequently, they were more open to trying out new ideas in science lessons and showed a greater commitment to changing their classroom practice. Findings from the post-intervention teacher questionnaires and interviews indicated an impressive increase in teachers' perception of their ability to teach science and to use pedagogical approaches such as hands-on activities. Teachers became more positive about teaching the curriculum content, developing pupil scientific skills and their own teaching skills. Most importantly, prior to intervention, teachers were more uncertain about teaching science, than teaching other subjects. Post-intervention, there was no difference. Teachers believed that participation in the programme gave them a sense that what they were doing was important not only for themselves but also for their pupils.

RQ3: *What changes in teachers' classroom practice occurred during the study?*

There is evidence from a variety of data sources (questionnaires, interviews and monitoring templates) which showed that the approach taken by the WSSP programme had a significant positive impact on the classroom practice of all the participants. Post-intervention, teachers indicated that they had changed the way they structured their science lessons. All 15 teachers interviewed indicated that they were using ideas, materials, and activities from WSSP, with their pupils. Many of them attributed these changes to the workshops, where they not only learned about innovative teaching methodologies, but also got the opportunity to experience them for themselves prior to teaching their own pupils. Teachers reported that involvement in the intervention programme steered them to develop and carry out more hands-on activities and classroom discussion in their lessons. A reason for this might be that the participants developed a deeper understanding of science concepts through hands-on experience (Radford, 1998). This, in turn, had a positive impact on their confidence to carryout hands-on activities in relation to those concepts.

The WSSP programme successfully changed teachers' practice; critical to this was the sense of ownership that occurred during the programme. This happened on two fronts: (1) the content of the workshops and (2) implementing change in their classrooms. Many of those who had previously used a primarily teacher-centred approach to teaching science were now using a pupil-centred approach – encouraging pupils to take responsibility for their own learning. The biggest change in teaching practice was teachers carrying out more open-ended practical work with their pupils. For various reasons as outlined in Chapter Nine, some teachers were committed to changing their teaching practice more than others.

RQ4: *What changes in pupils' attitudes towards school science occurred during the study?*

Research by Supovitz and Turner (2000) and Pell and Jarvis (2002) illustrated that CPD for teachers had a significant impact on pupil attitudes to primary school science. Evidence from this present study supports these findings. Results from the pupil questionnaires and interviews suggest that there is a relationship between the WSSP programme of CPD and pupils' attitudes towards school science, and that pupils as well as teachers benefitted from the programme. Findings showed that pupils' enthusiasm for school science became more positive, post-intervention, and the number of pupils who perceived science to be a difficult subject decreased – leading to more interest in school science. A very positive finding was the increase in the number of pupils who preferred science to other subjects (post-intervention).

Findings from the interviews with teachers also reinforced the view that CPD can improve pupil attitudes and learning experiences. All fifteen of the teachers indicated that the attitudes of their pupils towards school science changed in a positive sense as a result of their participation in WSSP. Teachers reported that their pupils were more confident, motivated, and gained greater satisfaction by taking a more hands-on part in the science lessons. These findings clearly support Guskey's (1986) argument that significant change in teachers' beliefs and attitudes only takes place after changes in pupil learning outcomes are evidenced. The WSSP programme was effective in developing positive attitudes to school science among pupils because: (1) it enhanced teacher knowledge and teaching skills, (2) better knowledge and teaching skills improved classroom teaching, and (3) more effective teaching increased pupil motivation and attitudes towards school science.

RQ5: *What changes in pupils' engagement and collaboration in hands-on science activities occurred during this study?*

In 2007, the European Union published a report (Rocard et al. 2007) on concerns about the declining interest of young people in science education. One of the main recommendations of the report, entitled *Science Education NOW: A Renewed Pedagogy for the Future of Europe* was the wider use of inquiry-based approaches in the teaching of primary science to help increase the interest of pupils in science (p. 2). According to the Primary Science Curriculum teacher guidelines (DES, 1999b), “first hand investigation is central to the way in which young people learn science. It equips them with the realisation that they can provide their own answers to problems and that they can learn from their interaction with things around them” (p. 2). The present intervention programme placed a very strong emphasis on encouraging teachers to allow their pupils to engage in hands-on, open-ended investigations in science lessons. The intervention programme brought about significant positive changes in pupils’ engagement and collaboration in hands-on activities. WSSP had a positive impact on the number of pupils engaging in hands-on activities in science classes. Findings from pupil questionnaires and interviews revealed that pupils were engaging in substantially more hands-on activities (especially open-ended investigations) as a result of their schools’ involvement in the WSSP programme. During the post-intervention interviews, pupils contrasted their experiences of science in the past (pre-intervention) with their most recent experiences (post-intervention). The most frequently mentioned differences were that they were now carrying out more experiments and that science was “more fun”.

These findings are supported by results from teacher interviews. Ten of the fifteen teachers interviewed revealed that the greatest benefit of the WSSP programme for them was the carrying out of hands-on activities. Furthermore, they mentioned that as a result of them engaging in the different types of hands-on activities at the workshops, their confidence in carrying out in hands-on activities increased. This encouraged them to allow their pupils to carry out more hands-on activities during science lessons.

The programme successfully changed pupil attitudes towards school science because the open-ended, hands-on activities and strategies experienced by teachers in the workshops, were implemented in many classrooms, making learning science more interesting and fun for pupils.

RQ6: *What aspects of the intervention programme promoted or inhibited teachers' subject confidence, competence and attitudes?*

Findings from teacher interviews and reflection monitoring templates were all very positive in response to this question. The teachers indicated that their participation in the project activities, including hands-on activities, collaboration with other teachers, relevant content, on-going discussion of teaching and learning, helped them learn a great deal more science content and gain confidence in teaching their pupils.

These factors that have made the WSSP professional development successful are not new breakthroughs in the field of professional development. They are characteristics of forms of professional development that have been documented for many years (see Chapter Five, section 5.2). The WSSP programme provided teachers with the opportunity to put certain features into practice – active participation, meaningful collaboration, continuity and feedback (Chapter Six, section 6.6). The results show that teachers deepened their science subject knowledge, raised their confidence in teaching science and developed positive attitudes towards science. This led to dramatic changes in their teaching practice, leading to positive results for their pupils. The implications of these characteristics for teacher professional development in primary science are discussed in the next section.

RQ7: *What aspects, if any, of the model influenced the development of "learning communities"?*

All the schools that participated in this study were small rural schools (two/three teacher) and hence had few professional interactions among staff. The project made significant inroads in breaking down that professional isolation and contributed to developing a learning community i.e. the coming together of teachers in a group to develop shared meaning and identify shared purposes to improve pupil learning (Hord 2009, p. 41). The on-going nature of the programme gave the participating teachers' time to reflect, both individually and as a group, upon their classroom practice; i.e. the workshops afforded teachers the opportunities and time to encourage reflection in a supportive environment.

As discussed in Chapter Seven (section 7.2.2), teachers' comments revealed that the WSSP programme, unlike other forms of professional development programmes they had experienced, encouraged them to: collaborate with colleagues from other schools; share ideas and resources; engage in pedagogical discussions about the successes and challenges of implementing innovative teaching methodologies. Outside of workshops, teachers exchanged ideas and resources on a virtual learning environment and collaborated in other areas, such as, trips and projects. The development of trust and collegial relationships between the facilitator and teachers, and amongst the teachers themselves, was probably the most important feature in developing a learning community.

11.2 Implications for the professional development of primary teachers in science

The research literature discussed in Chapter Five (section 5.2) highlighted the limitations of "one-off" type in-service courses, especially where promoting enduring changes in pedagogical practices are concerned. WSSP represents a form of professional development springing from a different conceptual basis and with a more discerning practical orientation. It primarily involves teachers themselves and draws pertinently on research literature. The experience from this study indicates that for professional development for teachers in primary science to be really fruitful, it should include the following key features: (1) be on-going and long-term; (2) have an emphasis on content and pedagogy; (3) be teacher driven and actively engage participants; (4) be collaborative in nature; (5) provide feedback and reflection; (6) have a system of evaluation.

On-going and long-term professional development

Successful professional development is a process, not an event, and needs to be sustained over time. The WSSP programme occurred over a two year period. During its planning and progress the researcher was mindful of important research by Supovitz and Turner (2000), that identified a strong relationship between the duration of professional development programmes and the enhancement of quality in pedagogical practice. Learning new content and pedagogical change requires time. This study showed that the professional development that occurred through workshops over a two –year period, allowed the participating teachers to: (1) change their own relationship to science by becoming more capable, more confident and more proactive in dealing with scientific concepts; (2) discover new pedagogical energies of their own from the sharing of ideas, experiences and challenges with their fellow participants; (3) gain a deeper understanding of how pupils learn, and of how they can best contribute to their own learning.

In addition to the workshops, the project's more informal learning experiences encouraged teachers to examine their own classroom practice, try out innovative teaching practices and gather feedback on their teaching. The interviews with teachers in this study, confirmed that most of the professional courses they had attended prior to this study were short in duration (between one to two days). The participants clearly preferred a longer period of CPD and saw WSSP as being of a more appropriate length of time for CPD.

An important finding of the programme showed, that it took some time for teachers to change their views and attitudes about school science, as well as their classroom practice.

The long duration of the study allowed teachers:

- the opportunity to establish trust and meaningful collaboration with other teachers, as well as with the researcher;
- the opportunity to learn in inviting, rather than anxiety-laden ways from and with other teachers;
- to try out activities picked up in workshops with their pupils back in the classrooms;
- to reflect on and discuss their classroom practice with colleagues.

It also enabled the researcher to plan the workshops as a series of scheduled events within a developmental sequence (Hogan et al., 2007) – each workshop contributing to the progressive development of specific capacities on the part of the participants (p. 100). The workshops also acted as a *reminder* to the teachers to focus on pedagogical issues in science, in their classroom practice: i.e. teachers knew that they would be called on to share ideas and offer accounts of their experiences and progress, at the next workshop. Not surprisingly, the findings from this study coincide with the research of Garet et al. (2001) which points out that "professional development is likely to be of a higher quality if it is both, sustained over time and involves a substantial number of hours" (p. 933). Such findings reinforce the point that professional development planners need to consider professional development as a long-term process of change, rather than isolated events.

Emphasis on content and pedagogy

Professional development programmes that are concerned with teachers' knowledge of specific subject matter and their awareness of how children learn that subject matter, are very effective at bringing about real change in teachers' knowledge, attitudes, and classroom practice (Kennedy, 1998; Garet et al., 2001). The WSSP programme directly addressed the content that pupils are expected to learn, problems teachers might encounter when teaching the content, and the teaching methodologies most suited to bringing about pupil learning in classrooms. In other words, the content was situated in, and relevant to, their classroom practice. Jeanpierre et al. (2005) argue that choosing the content of professional development may be the most significant decision to make when developing a professional development programme. Furthermore, they suggest that, "increasing teachers' knowledge of science and then having them apply that knowledge through actual experiences, supports substantial teacher learning and positive change in the classroom" (p. 671). Evidence from the present study revealed that prior to the implementation of the project, teachers lacked basic science knowledge, especially in the physical science area. This study revealed that there had been an over-reliance on the science textbook by teachers, a lack of awareness of how to develop pupils' inquiry skills, and a lack of understanding of how pupils learn in science.

The findings also show that WSSP helped the participating teachers to develop a deeper understanding of the particulars of the science curriculum and engaged them in learning science through inquiry at their own level. Most importantly, it placed a strong emphasis on the way pupils learn that content. Dana (1997) suggests that "teaching science so that pupils learn with understanding, requires that teachers understand child development, pedagogical and assessments alternatives, and scientific conceptual and procedural knowledge" (p. 427). Furthermore he states "A more productive model is one in which teachers are viewed as learners of science and science related pedagogy" (p. 428). Participants of WSSP indicated that they began afresh to understand science and the importance of pupils carrying out independent open-ended investigations. As teachers' understanding of science content and pedagogy increased, they became more comfortable and confident teaching science and were more prepared to use a variety of innovative teaching methodologies in their classrooms; bringing about productive changes in classroom practice. Such changes clearly makes science more interesting, and leads to better understanding and more positive attitudes to science, on the part of the learners.

Active engagement of participants in the process

The research discussed in Chapter Five (section 5.2) highlights that professional development is more meaningful to teachers when it is teacher-driven and when teachers are actively engaged in the process. Guskey (2002) found that teachers especially wanted to gain specific, concrete and practical ideas relevant to their classroom practice, from their professional development experiences (p. 382). This issue was addressed from the very start of the WSSP programme. During the design stage of the programme, participants were given a choice and were encouraged to take an active role in the design of the workshops. The workshop content varied from one workshop to the next in response to teachers' needs. Like pupils, teachers acquire new knowledge best by investigating for themselves. The WSSP programme provided teachers with the opportunities to engage in a range of hands-on activities that their pupils would subsequently experience. This made it easier to transfer new ideas to their classroom context i.e. the programme modelled the approach to teaching and learning that teachers were then expected to carry out in their classrooms.

The participants, by and large, referred positively to their experience of engaging in this type of learning. It convinced them that such activities would be equally engaging for their pupils (see Section 7.2.2). Such an approach to professional development provided the teachers with opportunities to shape and pace activities and discussions to suit their individual needs and not to be tied to the "outsider's" imposed agenda and timeframe. As the content was focused on their needs the teachers valued the experience more. All of them carried out the various activities experienced at the workshops with their pupils. However, as stated in Chapter Nine, (section 9.3) some teachers were more motivated than others and were more inclined to carry out more activities with their pupils. They reported their findings back to the other teachers at the workshops and had open discussions regarding their classroom practice. Such discussions were invaluable to the teachers; they motivated them to investigate themselves various activities discussed at the workshops back in the classroom. Most significantly, the discussions allowed them to see the other participants as additional sources of learning. Linking professional development to the classroom context and needs of the teacher is critical to the success of professional development programmes.

Programme highly collaborative in nature

Findings from this study indicate that for professional development to be most effective it needs to be collaborative in how it is planned and structured. As discussed in the previous section, collaborating with the participants prior to and during the programme should be an integral part of professional development.

The WSSP programme was highly collaborative in nature. During the workshops teachers were encouraged to work in groups. The make-up of the groups varied from workshop to workshop. The results from the teacher interviews (section 7.2.2) revealed that the participants saw collaboration as an important characteristic of professional development in breaking down teacher isolation. Teachers revealed how on-going sharing with other teachers on the programme gave them the support they needed to develop as learners: sharing of good ideas and resources between teachers; meaningful open discussions on pedagogical practice. Once they built up a trust and rapport among themselves and with the facilitator, the majority of participants spoke openly and frankly about their successes and difficulties in teaching science. They also took new risks in their classrooms without worrying too much about making mistakes, or the fear of failure.

Collaborative professional development programmes are critical for teachers in small rural (two or three teacher) schools. As stated in Chapter Five (section 5.6), teaching in such schools can be a very lonely professional experience. The collaborative approach used in this study encouraged teachers to support each other as a community of learners i.e. a network of learners. As the participants experienced the in-depth open pedagogical discussions they realised how isolated they were professionally in their own schools. Findings from this study indicate that when teachers had the chance to talk with colleagues about ideas and teaching strategies acquired during professional development, they were more likely to use them in their classroom practice.

Provision for feedback and reflection

All too often after attending a “traditional” form of professional development teachers are left on their own to implement what they have learnt back in their classroom. Planners of professional development programmes need to know that for a professional development programme to be effective and sustained it should provide participants with the opportunity to implement new ideas in their classroom practice. Feedback on teachers' efforts to change their classroom practice needs to be provided, if that change is to be sustained. Changes in teaching practice will not be sustained unless a teacher deems the change to have a positive impact on his/her pupils (Guskey 2002, p. 382). The WSSP programme was structured to provide participants with regular follow-up, feedback and support. This support definitely had a positive influence on teachers' confidence in teaching science. Guskey argues that "If the use of new practices is to be sustained and changes are to endure, the individuals [teachers] involved need to receive regular feedback on the effects of their efforts." (p. 387). When asked to comment on their experiences of professional development prior to WSSP, teachers mentioned (in a negative sense) that there was usually no follow-up on the part of the facilitators or no feedback given by the teachers (section 7.2.2).

The WSSP programme did not just demonstrate new techniques and deepen teachers' science knowledge, it asked teachers to explain and defend what they currently think and do in their classroom practice. Teachers were encouraged to question the innovative teaching approaches they were introduced to at workshops, why they should use these, when they should use them, and so on. Thus, teachers became more interested in their pupils' thinking, and how they learn. This was influential in leading to a change of teaching practice for many of the participants.

System for evaluation

The research literature relating to evaluation of CPD (Chapter Five, section 5.5) stressed that its consequences are seldom assessed over a long period. Evaluations are more often than not, all centred on self-reports by the teachers of the CPD event itself, rather than on the consequences of the CPD. Evaluation does not usually distinguish between the different purposes of CPD, and take account of the envisaged outcomes (Rose & Reynolds, 2006, p. 222). Muijs and Lindsay (2008) point out that "while the importance of CPD is widely acknowledged by the professions, evaluation of the impact of CPD is rarely undertaken in a systematic and focused manner" (p. 196). They add that too much emphasis is placed on participants' satisfaction with the CPD, and too little on the impact of CPD on teaching and learning. To date, this has largely been the situation with evaluation procedures undertaken by the national CPD providers in

Ireland. Large investments have been made in CPD at national level by the DES. The question needs to be asked, how effective has this CPD been?

The present study placed a strong emphasis on evaluation of teacher and pupil outcomes throughout the CPD process i.e. evaluation played an integral role in the programme. The evaluation of how effective a CPD programme is requires the use of suitable methods. This study used various methods and approaches to assess the effect of the study on classroom practice. Evaluations were in the form of questionnaires, interviews, cognitive tests and various documents, administered before, during and after the study. It also successfully adopted Guskey's "five levels of evaluation" approach to CPD (discussed in Chapter Five, section 5.5). This allowed the study to determine outcomes at teacher and pupil level. Findings from the teacher interviews and reflection monitoring templates showed that the programme encouraged teachers to change their classroom practice, deepen their science knowledge, and become more enthusiastic and confident teaching science. Evaluation of findings from pupil interviews and questionnaires suggested that over the duration of the programme, pupils in the participating schools developed more positive attitudes towards school science. As well as informing the researcher about the outcomes of the programme, evaluation, in the form of monitoring reports, workshop reflections and informal visits to schools enabled the researcher to change various aspects, such as, content, or timetabling during the programme.

Independently, the features discussed above are not new. However, this study has shown that linking them together in a framework increases the potential of developing effective long-term professional development for teachers.

11.3 Limitations of the study

Prior to discussing the recommendations of this research study, it is important to be aware of a number of limitations associated with this study:

- The first limitation of this study deals with the methods used, which included teacher questionnaires and interviews. This was a study (1) of teachers' perceptions of developments in their own practice, and (2) of pupils' perceptions of developments in their attitudes and practices where learning science is concerned. In order to find out if the teachers really have changed their classroom practices as a result of CPD, data should be collected from various sources, including classroom observation. However, because of a lack of resources (human and financial) the researcher was unable observe classroom practice in a formal way and/or measure the extent to which teachers, as a result of WSSP, changed their classroom practice. Formal classroom observations carried out prior to, and towards the end of the programme, would have given the study an extra measure of validity and reliability.

- Secondly, the study was only concerned with the affective domain of pupil participants, and not with their cognitive domain. Pre- and post-intervention questionnaires and interviews were carried out to assess whether pupils attitudes towards school science had changed as a result of their teacher's involvement in WSSP. Pre- and post-intervention achievement tests in science for the pupils would have enhanced the findings of the study as to whether the programme had had an effect on pupil learning outcomes.

- The third limitation of the research, is the absence of a control group to determine the extent of change the intervention programme brought about in teachers' attitudes or classroom practice. The teachers who participated in the project (experimental group) received incentives (human and resources) for their participation. For any potential control group to take part in the programme there would need to be some meaningful benefits for them. Also as there was only a limited amount of funding, it was not possible to provide incentives to a potential control group.

- Finally, the selection of participants for the programme can also be viewed as potentially problematic. Schools were selected by the Department of Education and Science inspectorate and the Irish American Partnership. This confined the study to small rural (two/three teacher) schools in limited geographical locations. However, examination of the participants (Chapter Seven, section 7.1) shows that they by and large reflect the general teacher population in terms of qualifications, gender and teaching experience.

11.4 Recommendations

The primary purpose of this research was to develop a model of professional development in science education with primary teachers in 15 small rural schools, in order to enhance the teaching and learning of primary science in these schools. While noting the limitations of this study and its findings, it is possible to suggest recommendations for future continuous professional development generally and not just in the area of science education.

Pre-service teacher education

As the groundwork for effective teaching happens during pre-service education, pre-service teachers must be offered sufficient time to gain adequate knowledge and understanding of science – a mixture of science content knowledge and pedagogical content knowledge. Teacher education programmes in Ireland for primary teachers offer, between 12 hours and 44 hours of science education over the three year degree period and 20 hours for the postgraduate programme. Clearly, this is not enough time for teachers to enhance their science knowledge and skills. In fact, it is a lot less than other subjects such as, music and art. One of the recommendations of The Task Force on Physical Sciences (2002) is “pre-service providers must ensure that there is sufficient time to fully address both pedagogy and science content” (p. 122). Teacher education colleges offer elective “specialist” courses in a variety of subjects such as music and history. However, to date, none of them offer elective “specialist” science education courses. As well as enhancing pre-service teachers’ science and pedagogical knowledge, such a course would also encourage them to develop positive attitudes towards science. This would help to cultivate positive attitudes towards science on the part of their future pupils and colleagues in school. At present, Bachelor of Education (B.Ed) courses for primary teachers in the five Teacher Education Colleges are three years in duration. The Department of Education and Skills are currently in the process of approving a four year framework for such courses. With this in mind, the following recommendations should be considered:

- Teacher education colleges should provide more time for pre-service teachers to study science education during their training, and offer contemporary science courses that provide a solid background in science content, pedagogical knowledge and pedagogical content knowledge (Shulman, 1986);

- Teacher education colleges should provide a “specialist” science course for pre-service teachers with an interest in science education which would be similar in time allocation and status to the other academic subjects currently offered at teacher education colleges;

- The Teaching Council should recommend that all primary teachers should graduate with a suitable standard of scientific knowledge i.e. a standardisation of science education across all teacher education colleges. Ensure that all future Irish primary teachers would have a minimum scientific understanding in order to teach science effectively in primary school. Such a recommendation would require an amendment to the Teaching Council Regulations for primary teachers.

Teacher Continuing Professional Development

Continuing professional development (CPD) is important for all professions. However, in the Irish context the undertaking of CPD is not compulsory for teachers. Some professions such as accountancy and law have recognised the importance and benefits of CPD and have made it compulsory. They are required by legislation or by internal policy of the profession to take part in a certain number of prescribed hours of CPD per year or over a certain timeframe. For other professional bodies, such as nursing, CPD is not compulsory; however, it is very much encouraged and is a fundamental part of the system. The statutory body for nursing (An Bord Altranais 2000) requires nurses to be competent in all areas in which they are working and to up skill themselves in areas in which their competency is limited (p. 6).

Professional development for teachers is an issue of concern both in Ireland and other European Union countries (EU). The EU regards the role of teachers and their continuing professional development as one of its key educational priorities. The document, *Common European Principles for Teacher Competences and Qualifications (2005)* states:

> Teachers should be supported in order to continue their professional development throughout their careers. They and their employers should recognise the importance of acquiring new knowledge, and teachers should be able to innovate and use evidence to inform their work. They need to be employed in institutions which value lifelong

> learning in order to evolve and adapt throughout their whole career. (p. 2).

The dominant theme emerging from this statement is that professional development should be a continuous process lasting for a professional lifetime. Also, policies and strategies should reinforce this.

Eurydice, the European data network on education (Eurydice, 2009), provides an outline of CPD for school teachers (primary and post-primary) in European countries. All the countries within the European Union provide professional development opportunities for teachers; however, this varies between countries. In over half of all European countries (e.g. Belgium, Germany, the Netherlands, Austria, Sweden, the UK, Estonia, Latvia, Lithuania) professional development forms an integral part of a teacher's professional duties and is compulsory. In other countries (e.g. Spain, Poland, Portugal, France, Slovenia and Bulgaria) professional development is optional. However, in practice, teachers' promotional prospects and earnings depend on their evidence of professional development. At present there is no requirement for teachers in Ireland to undertake and record CPD. There is a consensus among the various stakeholders; unions, teachers and state, regarding the need for the provision of formal CPD. Unfortunately, practical aspects, such as, when it should be provided, and whether or not it should be compulsory, remain very contentious issues. For example, should it be done inside or outside of class time? Should the school year be lengthened? Should CPD be incorporated into the existing school year? The failure to address these issues in a thorough and rigorous manner has limited the advancement of professional development activities in the Irish educational system.

Traditionally, programmes of professional development as understood in the Irish context tend to be based on provider driven "one-off" or short modular courses centrally provided for by the Department of Education and Skills, through various national support agencies. The OECD TALIS survey (2009) reported that the professional development courses attended by Irish teachers mostly related to changes in subject syllabi and the implementation of national curriculum programmes, with little emphasis on the professional development needs of individual teachers and schools. By definition, provision of this nature tends to be subject-specific and is inclined to prioritise the needs of the system. The professional development needs of the teacher have not featured particularly strongly in recent DES developments. Granville (2005) maintains that the concept of continuing professional development (CPD) is well established in policy rhetoric but less well established in practice at the level of the teacher and the school (p. 58). A key challenge for the future is the development of a system of professional development that will support and encourage individual schools and teachers to carryout school-based, collaborative, relevant, on-going and sustained professional development activities.

The Croke Park Agreement of 2011 (a new public service pay and reform deal designed to deliver financial savings through job reform and cutbacks) can provide an opportunity for teachers to engage in CPD. To bring this about it is vital that all the stakeholders – state, support agencies, Teaching Council and unions – are acting in concert. “In those jurisdictions where such solutions have been imposed, much of the good they might bring is frustrated, sometimes for years.” (Hogan et al., 2007, p. 83). The Agreement can be used as a vehicle to (1) encourage teachers to participate in CPD activities; and (2) undertake a minimum requirement of CPD hours and keep a record of their learning experiences as evidence of their achievements. It would also allow for CPD to be seen as an integral part of a teacher’s professional experience and not just as an “add on”. According to the Agreement, school management may designate the use of the extra hours (33 hours for post-primary and 36 for primary) to provide additional time to deal with some or all of the following items:

- School planning and policy development (including subject planning);
- Staff meetings;
- Parent teacher meetings (in line with the agreed formula for such meetings);
- Induction;
- Nationally mandated in-service/continuing professional development e.g. new programmes or syllabi;
- Approved school arranged in-service/continuing professional development;
- Appropriate further education activities;
- Substitution and supervision.

These items emphasise the needs of the system, the school and the individual teacher. However, they don’t differentiate between them. The provision of CPD in the last two decades has mainly been concerned with the needs of the system. A minimum number of these hours should be clearly demarcated for the professional development needs of the individual teacher in the area of teaching and learning. There needs to be a framework put in place to encourage schools and principals to provide for all three types of CPD and to reflect on the particular needs of their schools and the individual teachers. Support agencies, Education Centres, DES and unions also have a role to play here. A worry is that the extra hours will be used up dealing with administration issues, rather than issues concerned with teaching and learning in the classroom. Principals and schools should be provided with a reasonable budget which could address the CPD priorities of the school and the teachers.

Scotland, a country comparable in population size to Ireland, provides an example of a country which contains many features of best practice in CPD. While the specific details of Scotland's education system remain particular to Scotland, we could learn many lessons from its education development could be tailored to suit our particular needs and circumstances.

At the turn of the century in Scotland, the notion of forming a "Teaching Profession for the 21st Century" was introduced by the Scottish Executive Education Department (SEED). After consultation with members of the educational community, such as, unions, teachers, and councils, the agreement *A Teaching Profession for the 21st Century* (Scottish Executive Education Department, 2000) was produced. This agreement brought about the formation of a national framework of continuing professional development. The agreement recognised the importance of CPD, both as a professional entitlement and a professional obligation. Key features of the agreement included:

- Teachers have an on-going commitment to maintain their professional expertise through an agreed programme of continuing professional development.

- An additional contractual 35 hours of CPD per annum, introduced as a maximum for all teachers, consisting of an appropriate balance of personal professional development, attendance at nationally accredited courses, small scale school based activities or some other CPD activity. This balance is based on an assessment of individual needs taking account of school, local and national priorities and shall be carried out at an appropriate time and place.

- Every teacher has an annual CPD plan agreed with her/his immediate manager and every teacher is required to maintain an individual CPD record.

- It is the employer's responsibility to ensure a wide range of CPD development opportunities and the teacher's responsibility to undertake a programme of agreed CPD which should be capable of being discharged within contractual working time.

Most significantly, these key features do three important things: (1) cater for the teacher's individual needs as well as the systems; (2) ring-fence time for CPD; (3) place an obligation on school and teacher to commit to CPD. The Scottish framework of CPD offers promising options that could help bring about major changes that are needed in CPD provision for teachers in Irish schools.

Prior to the Croke Park Agreement the Scottish type of CPD framework would have presented a radical change in CPD provision in Irish schools. However, the Agreement provides an ideal opportunity towards developing the first steps of a national framework of continuing professional development. Most importantly, for an idea such as this to take root within the system there needs to be consultation between the various stakeholders – unions, teachers, Teaching Council, DES and other members of the educational community. This requires a significant change in the cultural mindset of the various stakeholders and one that will not be easy to achieve, but is however, achievable. By addressing issues of teachers' morale, professional autonomy, and public accountability, a national framework of CPD was developed in Scotland.

New role for Education Centres

The evidence from this study shows that a local, clustered approach to professional learning has substantial benefits, especially for teachers in small rural primary schools. However, in order for such a clustered approach to be sustainable and further developed, there is a need to provide regional venues along with trained local co-ordinators. The Education Centre network could provide this. The Education Centre network (21 full-time and 9 part-time) have a key role to play in the provision of teacher CPD. According to the Association of Teacher Education Centres Ireland (ATECTI), the core function of Education Centres is to:

1. Deliver in-service training to support system needs as determined by the Department of Education and Skills.
2. Design and deliver training in response to locally researched and identified needs.

Traditionally Education Centres have invested considerable time and effort in addressing the system's needs (1) above; coordinating top-down national continuous professional development programmes – such as the introduction of new syllabi and programmes at Post-Primary level and hosting the Primary Curriculum Support Programme at primary level. However, in relation to the second core function above, "design and deliver training in response to locally researched and identified needs", much work remains to be done by the Education Centres in relation to providing for the needs of schools and their individual teachers. To date, their potential is somewhat under-utilized in this important area and they now need to adopt a more central role in organising (not just facilitating) CPD for teachers from their locality. As Education Centres are based locally they can reliably gather information on the needs of schools and teachers and can help organise professional development suitable to those needs. They could also act as a vehicle in the initiation and promotion of local professional learning communities. A number of Education Centres are already up and running at this work and are involved in some very positive and promising local CPD initiatives.

Accreditation of CPD

There is a need to develop a framework that accommodates more than one form of accreditation in CPD. Traditionally, accreditation in CPD for teachers in Ireland occurs through a university route; i.e. participants study for a postgraduate qualification. According to Hogan et al. (2007) "...university accreditation involves pupils in scholarly disciplines that include serious and sustained reading and the production of significant quantities of writing" (p. 84). This type of accreditation will only appeal to certain teachers. There is a need for a non-university form of accreditation, as a means of rewarding those teachers who want to pursue accreditation without having to leave the classroom.

The award of "Charter Teacher" devised by the General Teaching Council in Scotland provides an option for teachers who want to pursue a non-university accreditation route. It involves teachers developing portfolios around the teaching and learning that occurs in their classroom, allowing the teacher to investigate, reflect on and further develop his/her practice. The Teaching Council in Ireland has, as part of its remit, the promotion of CPD of teachers. It is encouraging to see in its discussion document on the *The Continuum of Teacher Education* (2011) that “programmes of CPD should be accredited by The Teaching Council having regard to its statutory powers under Section 39 of the Teaching Council Act, 2001” (p.19). This looks like the first indication of a non-university accreditation route for CPD for Irish teachers.

11.5 Further research – scaling and sustaining change

The findings discussed earlier have shown that the WSSP programme has been a very effective form of professional development for those teachers who participated in it. It is crucial to ensure that the insights, lessons and practices that the project’s participants have generated are sustained and developed further. If the WSSP approach is to effect more than the 15 schools in the programme and become part of the national picture, it must have the opportunity of reaching most schools in a sustainable way. As a result of the success of the WSSP project the Irish American Partnership have agreed to provide funding to the researcher to transfer the programme from a research and development pilot stage, to a mainstream stage (WSSP Transfer Initiative). It is the researcher’s intention to coordinate the Transfer Initiative through the Education Centre Network in consultation with key national education agencies such as, DES, PDST and the INTO. The Transfer Initiative will give the Directors of the Education Centres the opportunity to work closely with teachers in the local schools, assessing their individual and collective needs, organising workshops within and/or between individual schools (clustering) and encouraging networking between local schools. This approach is modelled on the TL21 Transfer Initiative professional learning model (discussed previously) which is proving successful in effecting teacher change amongst teachers at post-primary level. At the time of writing the researcher is in discussions with the Director of one of the Education Centres to engage him in the planning and organising of professional development workshops using the features that proved most productive during the WSSP project. It is intended to appoint a co-ordinator to work closely with the Education Centre Director and the WSSP researcher. The role of the co-ordinator will include: recruiting appropriate schools; liaising with and visiting participating schools; organising workshops; developing a close, trusting and supportive relationship with the participants.

The present economic crisis has resulted in the limitation of government supported professional development opportunities for teachers in the area of primary science. However, it is the researcher's considered belief that the WSSP Transfer Initiative could offer an effective and affordable form of professional development, chiefly because it provides a low cost model needing only one co-ordinator to work with a cluster of schools.

11.6 Conclusion

As far as the researcher can ascertain this kind of research study has not been carried out in Irish primary schools before now. The findings of this study should therefore make a distinct contribution to the available body of research literature in the area of primary science education and professional development.

Evidence reported in this study shows that, prior to intervention, the participating teachers clearly needed professional development in the teaching of primary science. This is consistent with findings from the international literature which shows that most primary teachers are not sufficiently prepared to teach science effectively. The current study also shows that the type of professional development they received (encouraging teachers to reflect on their beliefs, knowledge and learning and to share their ideas with colleagues) was very effective, with participants becoming substantially more confident and competent in teaching primary science. Most significantly, teachers made dramatic changes in the way they teach science, resulting in their pupils becoming more positive and motivated to learn science. Most of the findings of the study are in harmony with those reported in the research literature reviewed in Chapters Four and Five. An additional finding of this study indicates that major inroads were made into reducing the professional isolation of teachers in small rural schools.

Continuing professional development is necessary for improvement in Irish schools. Recent professional development initiatives such as the TL21 project, TL21 Transfer Initiative, and the present study, had notable positive effects upon the individual teachers, school leaders, and pupils at primary and post-primary level. In Ireland, in the present economic downturn, support for effective CPD is not sufficiently high on the education priority list. However, it is imperative for the government to reconsider this situation and prioritise and provide funding for CPD. Effective CPD can increase teachers' knowledge and skills, enabling them to teach their pupils effectively. The teacher is the most important person in education reform and the key to success lies in the support the teacher receives. As Thomas Guskey (2000, p.4) concludes, "One constant finding in the research literature is that notable improvements in education almost never take place in the absence of professional development".

References

Aikenhead, G., & Ryan, A. (1992). The development of a new instrument: 'Views on Science-Technology-Society' (VOSTS). *Science Education,* 76, 477-492

Ajzen, I. & Fishbein, M. (1980) *Understanding attitudes and predicting social behaviour* (Englewood Cliffs, NJ, Prentice Hall).

American Association for the Advancement of Science [AAAS] (1993). *Benchmarks for Scientific Literacy: Project 2061.* New York, Oxford University Press. Also available online: http://www.project2061.org/tools/benchol/bolintro.htm

American Educational Research Association (Summer 2005). *Teaching Teachers:*

An Bord Altranais (2000) *The Code of Professional Conduct for each Nurse and Midwife April 2000*

Appleton, K. (2003) How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. Research in Science education Vol (22) pp. 1 – 25.

Appleton, K., & Kindt, I. (1999). Why teach primary science? Influences on beginning teachers' practices. *International Journal of Science Education,* 21(2), 155-168.

Australian Science, Technology and Engineering Council. (1997*) Foundations for Australia's future: Science and technology in primary schools.* Canberra, Australia: Australian Government Publishing Service.

Barraza, L. (1999) children's drawings about the environment *Environmental Education Research,* 3 (1) 49 – 66

Beggan, G. (1988) A Profile of the Progress of Science in Primary Education in Ireland, 1837-1986, *Oideas,* Vol. 32, p. 36-50

Bennett, S. N., Wragg, E. C., Carre, C. G. & Carter, D. S. G. (1992) A longitudinal study of primary teachers' perceived competence in, and concerns about, National Curriculum implementation. *Research Papers in Education,* 7(1), 53-78.

Black, P. (1993) 'The purpose of science education', in Whitelegg, W., Elizabeth, L., Thomas, J. (eds.) Challenges and Opportunities for Science Education, London: Paul Chapman Pub.

Bolam, R., McMahon, A., Stoll, L., Thomas, S., & Wallace, M. (2005). *Creating and sustaining effective professional learning communities*. Retrieved September 28, 2009, from http://www.dcsf.gov.uk/research/data/uploadfiles/RB637.pdf

British Council for Science and Technology (2000). Science Teachers: A Report on Supporting and Developing the Profession of Science Teaching in Primary and Secondary Schools (London: Council for Science and Technology).

Brookfield, S. (1995) *Becoming a Critically Reflective Teacher.* San Francisco: Jossey Bass

Brown, A.J. & Dowling, P.C. (1998). Doing Research/Reading Research: a mode of interrogation for education. London: Falmer Press.

Burbules, N.C. (2000) *Constructivism: Moving Beyond the Impasse*. Retrieved June 15, 2009 From http://faculty.ed.uiuc.edu/burbules/papers/construct.html

Bybee, R.W. (1991) *Reforming Science Education-Social Perspectives and Personal Reflections.* New York: Columbia University, Teachers College Press.

Callan, J. (2006) *Developing Schools Enriching Learning: The SED Experience:* Martone Press Dublin

Carr, W. & Kemmis, S. (1986) Becoming Critical: education, knowledge and action research. Lewes, Falmer.

Carré C, Carter D. (1993) Primary teachers' self-perceptions concerning implementation of the National Curriculum for science in the UK –revisited. *International Journal of Science Education 1993*; 15(4):457–70.

Champagne, A. B. (1989) Defining Scientific Literacy. *Educational Leadership,* 47(2), 85-86

Childs, P. (2002) Securing the future of chemistry: A case study of developments in chemical education in Ireland. Chemistry Education, Vol. 3, No. 3, pp. 361-369

Clarke, D J , & Hollingsworth, H (2002) Elaborating a model of teacher professional growth *Teaching and Teacher Education*, 18(8), 947-967

Cohen, D.K., & Hill, H. (1997) *"Instructional Policy and Classroom Performance: The Mathematics Reform in California."* Manuscript.

Cohen, L. Manion, L. & Morrison, K., (2000) *Research methods in education*, (5th Edition) Routledge Falmer.

Coll, R.K. & Taylor, T.G.N. (2001) Using constructivism to inform tertiary chemistry pedagogy. Chemistry Education: Research and Practice in Europe, 2 (3), 215-226

Coolahan, J. (1981) *Irish Education History and Structure*: Institute of Public Administration

Corroon, C. (2005) Teachers' Perceptions of the implementation of the Primary Science Curriculum (1999). Masters in Education St. Patrick's College, Dublin City University

Costa, A. & Kallick, B. (1993) Through the Lens of a Critical Friend. *Educational Leadership* **51** (2) 49-51

Creswell, J.W. (2003). *Research design: Qualitative, quantitative, and mixed approaches*. Thousand Oaks, CA: Sage.

Dana, T. M., Lois M. Campbell, L. M., Vincent N. Lunetta, V.N. (1997). Theoretical Bases for Reform of Science Teacher Education. *The Elementary School Journal*, Vol. 97, No. 4, pp.419-432

Darling-Hammond, L. & McLaughlin, M.W. (1995, April). Policies that support professional development in an era of reform. *Phi Delta Kappan*, 76(8), 597-604.

Dawson, V. (2009) Science is Primary: A Review of Primary Connections Stage 3 downloaded from www.science.org.au/primaryconnections on 20th September 2011

Day, C. (1999) *Continuing professional development.* London: Falmer Press.

De Jong, O. (2007). Trends in western science curricula and science education research: a bird's eye view, *Journal of Baltic Science Education, 6*(1), 15-22.

Denscombe M. (2007) *The Good Research Guide*, England: Open University Press.

Department of Education (1926) *The Teaching of Rural Science and Nature Study in Primary Schools* – Regulations and Explanatory Notes for Teachers Dublin, Stationary Office

Department of Education (1934) *Revised Programme of Instruction* Dublin, Stationery Office

Department of Education (1971), Curaclam na Bunscoile – Primary School Curriculum, Teachers' Handbooks (2 vols) Dublin: The Stationery Office

Department of Education (1983) *Daoneolas agus Eolas Imshaoil – Tuairisc ar Fheidhmiu an Churaclaim sna Bunscoileanna*, Dublin, an t-Aonad Curaclaim, Department of Education, p.14

Department of Education and Science (1999) *Primary school curriculum – Introduction*, Dublin: The Stationery Office

Department of Education and Science (1999a) *Primary school curriculum: Science,* Dublin: The Stationery Office

Department of Education and Science (1999b) *Primary school curriculum: Science - Teacher guidelines*, Dublin: The Stationery Office

Department of Education and Science (1999c) *Primary Curriculum Support Programme,* Dublin: The Stationery Office

Department of Education and Science (2004). *Tuarascáil Statisticiúl [Statistical Report], 2002-2003.*Dublin: Government Publications.

Department of Education and Science (2003) *Annual Report 2003,* Dublin: Department of Education and Science

Department of Education and Science (2005) *An Evaluation of Curriculum Implementation in Primary Schools,* Dublin The Stationery Office.

Department of Education Northern Ireland (1996) *The Quality of Teaching and Learning in English, Mathematics and Science in a sample of primary schools.* Bangor, Northern Ireland,DENI.

Department of Enterprise, Trade and Employment (2006) *Strategy for Science, Technology and Innovation 2006-2010.* Dublin: Government Publications Office

Doyle, S. (2009) Pedagogy, values and career fulfilment: evaluation of a science CPD programme *Improving Schools*; 12; 145 – 159

Doyle, L. Brady, A. & Byrne, G. (2009) An Overview of Mixed Methods Research. *Journal of Research in Nursing*,14, (2), 175-185

Driver, R. (1983) *The Pupil as Scientist?* Milton Keynes: The Open University Press.

Driver, R. & Bell, B. (1986) Pupils' thinking and the learning of science: a constructivist view. *The School Science Review*, **67**(240), 443-456.

Driver, R., Guesne, E. & Tiberghien, A. (Eds) (1985) *Children's Ideas in Science* (Milton Keynes, Open University Press).

Education Review Office (1996). Science in schools –implementing the 1995 science curriculum Wellington: Education Evaluation Reports.

Elliott, J. (1991) *Action Research for Educational Change,* Buckingham, Open University Press.

European Commission (2005), *Common European Principles for Teacher Competences and Qualifications*.

Eurydice (2009) Information on Education Systems and Policies in Europe. Accessed on 9th February, 2011 from http://eacua.ec.europa.eu/education/eurodice_index_en.php

Fensham,P.J. (1988) Science for All: A reflective essay. *Journal of Curriculum Studies,* 17(4), 415-435

Fensham, P.J. (1992), 'Science and Technology', in P.W.Johnston (Ed) *Handbook of Research in Curriculum* Macmillan, New York, pp 789 – 829

Fensham, P. (2002). Science for all. In Wallace, J., Louden, W. (ed) (2002). *Dilemmas of science teaching: perspectives on problems of practice*. Routledge, Falmer. London

Ferrance, E. (2000) Action research, *Themes in Education* Retrieved 20th Augest, 2011, from http://www.alliance.brown.edu/pubs/themes_ed/act_research.pdf.

Fraser, B. J. (1981). *Test of Science-Related Attitudes handbook (TORSA)*. Melbourne, Australioa: Australia Council for Educational Research.

Fullan, M. (1991) *The New Meaning of Educational Change* (New York, Teachers College Press).

Fullan, M. & Hargreaves, A. (1996). *What's Worth Fighting for in Your School…* New York: Teachers' College Press.

Gardner, P. L. (1975) Attitudes to science: a review, *Studies in Science Education*, 2, 1–41.

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), 915-945.

Giordano, E.A. (2008). School clusters and teacher resource centres UNESCO Retrieved on 2nd November 2009 http://unesdoc.unesco.org/images/0015/001597/159776e.pdf

Glaser, B.G., & Strauss, A.L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research.* Chicago: Aldine

Golby, M., Martin, A & Porter, M (1995) Some researchers' understanding of primary teaching, *Research Papers in Education*, 10, pp. 97-302

Goodrum, D., Hackling, M., and Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report.* Canberra, ACT: DETYA.

Government of Ireland (1995) *Charting Our Educational Future*. Government White Paper. Dublin: Stationary Office.

Government of Ireland (1996) *Science, Technology and Innovation* Government White Paper. Dublin: Stationery Office

Government of Ireland (1998) Education Act, (Dublin, Stationery Office).

Government of Ireland (1999) *Ready to Learn: White Paper on Early Childhood Education*, Dublin: The Stationery Office.

Government of Ireland (2000) *Learning for Life: White Paper on Adult Education,* Dublin: The Stationery Office

Government of Ireland (2000) The Education and Welfare Act (Dublin, Stationery Office).

Government of Ireland (2000) *Report of the Joint Oireachtas Committee on Education and Science on Science and Technology.*

Government of Ireland (2004) *Building Irelands' Knowledge Economy – The Irish Action Plan for Promoting Investment in Research and Development to 2010.*

Government of Ireland (2006) *The Strategy for Science, Technology and Innovation Report (2006-2013)*

Granville, G. (2005) *Cultivating Professional Growth: An Emergent Approach to Teacher Development*.

Guskey, T. R. (1986) Staff development and the process of teacher change, *Educational Researcher,*15 (5), pp. 5-12.

Guskey, T. R. (1995). Professional development in education: In search of the optimal mix. In T. R. Guskey & M. Huberman (Eds.), *Professional development in education: New paradigms & practices* (pp. 114-132). NY: Teachers College, Columbia University.

Guskey, T. R. (2000) *Evaluating Professional Development* (Thousand Oaks, CA, Corwin Press).

Guskey, T.R. (2002) Professional Development and Teacher Change. *Teachers and Teaching: theory and practice, 8*,(3/4*)*,381-391

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan, 84*(10), 748-750

Guskey, T. R. & Huberman, M. (1995) *Professional Development in Education: new paradigms and practices* (New York, Teachers College Press).

Hackling, M., Peers, S. & Prain, V. (2007). *Primary Connections*: Reforming science teaching in Australian primary schools. *Teaching Science, 53*(3), 12-16.

Haladyna, T., Olsen, R. & Shaughnessy, J. (1982). Relations of pupil, teacher learning environment variables attitudes towards science, *Science Education* Vol. 66, No. 5, pp. 671 687

Harlen, W. (1996) *The Teaching of Science in Primary Schools,* (2nd edition), London: David Fulton Pub.

Harlen, W. (1997) Primary teachers' understanding in science and its impact in the classroom. *Research in Science Education*, 27(3), 323-337.

Harlen, W. (1998) The last ten years; the next ten years, in: Sherrington, R (1998) ASE Guide to Primary Science Education. Cheltenham: Stanley Thornes

Harlen, W. (2001) Review: Research in Primary Science Education, *Journal of Biological Science, 35(2), 61-65*

Harlen, W. & Holroyd, C. (1997) Primary teachers' understanding of the concepts of science: impact on confidence and teaching, *International Journal of Science Education,* Vol. 19, No. 1, pp. 93 – 105

Harlen, W. & Qualter, A (2007) *The Teaching of Science in Primary Schools,* (4th edition), London: David Futlon Pub.

Harlen, W., Holroyd, C. and Byrne, M. (1995) *Confidence and Understanding inTeaching Science and Technology in Primary Schools.* Edinburgh: Scottish Council for Research in Education.

Harms, N. & Yager, R.E. (eds) (1981) *What research says to the science teacher, vol 3.* Washington D.C.: Boulder: University of Colorado.

Hashweh, M. Z. (1987). Effects of subject matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education, 3*, 109-120.

Hawley, W. D. & Valli, L. (1999). The essentials of effective professional development. In L. Darling-Hammond, & G. Sykes, (Eds.), *Teaching as thelearning profession: Handbook of policy and practice*, San Francisco: Jossey-Bass.

Hawley, W. D. & Valli, L. (2000) Learner-Centered Professional Development. *Phi Delta Kappa International*, 27, 1-7

Hoban, G. F. (2002) *Teacher Learning for Educational Change* Buckingham: Open University Press

Hogan, P., Brosnan, A., deRóiste, B., MacAlister, A., Malone, A., Quirke-Bolt, N., Smith, G. (2005) *Voices from School*: Interim Report of the Teaching and Learning for the 21st Century, Project 2003-2007, Maynooth University.

Hogan, P., Brosnan, A., deRóiste, B., MacAlister, A., Malone, A., Quirke-Bolt, N., Smith, G. (2007) *Learning Anew*: Final Report of the Teaching and Learning for the 21st Century, Project 2003-2007, Maynooth University

Holroyd, C. & Harlen, W. (1996) Primary teachers' confidence about teaching science and technology, *Research Papers in Education*, Vol. 11, No. 3, pp.323-335

Hord, S. M., (2009) Professional Learning Communities, National Staff Development Council Vol. 30, (1), pp 40-43

Hueftle, J.S., Rakow, S.J.,& Welch, W. W.(1983) *Images of Science.* Minneapolis. MN: University of Minnesota, Minnesota Research and Evaluation Centre

Hughes, P. (1991). *Teacher's professional development*. Hawthorn: The Australian Council for Educational Research.

Hurd, P. D.(1983) State of precollege education in mathematics and science. *Science Education 66*(2) 281-285.

Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, pupil outcomes and efficacy. *Education Policy Analysis Archives*, 13(10), 1-28.

International Assessment of Educational Progress (IAEP). (1988) *A world of difference: summary report of an international assessment of mathematics and science, report no. 22-CAEP-02,* New Jersey: Educational Testing Service

Irish Council for Science Technology and Innovation (1998) *Science in Primary Schools.*

Irish National Teachers' Organisation (1947) *A Plan for Education*. Dublin: INTO

Irish National Teachers' Organisation (1976). *Primary School Curriculum Questionnaire Analysis*. Dublin: INTO.

Irish National Teachers' Organisation (1987) *Primary Science Curriculum*. Report and Discussion Papers Dublin: INTO

Irish National Teachers Organisation (1992) Primary Science Education in Ireland: Issues and Research (No 16/92), Dublin: INTO

Jarvis, T. & Pell, A. (2002) Changes in primary boys' and girls' attitudes to school and science during a two-year science in-service programme. *The Curriculum Journal* ,13,(1), 43-69

Jarvis, T. & Pell, A. (2004) Primary teachers changing attitudes and cognition during a two-year science in-service programme and their effect on pupils, *International Journal of Science Education*, 26(14), 1787–1811

Jarvis, T., Pell, A. & McKeon, F. (2003) Changes in primary teachers' science knowledge and understanding during a two year in-service programme. *Research in Science & Technological Education*, 21,(1), 17-42

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005) Characteristics of professional development that effect change in secondary science teachers' classroom practice. *Journal of Research in Science Teaching* 42, 6, 668-690

Johnston, J. (1996) *Early Explorations in Science Buckingham*: Open University Press

Johnston, K., Murchan, A., Loxley, A., Fitzgerald, H., Quinn, M. (2007) The Role and Impact of the Regional Curriculum Support Service in Irish primary education, *Irish Educational Studies, 26 (3) 219- 238*

Johnson, R.B., & Onwuegbuzie, A.J. (2004) Mixed methods research: a research paradigm whose time has come. Educ ation Research 33: 14–26.

Kennedy, A. (2005). Models of Continuing Professional Development: a framework for analysis *Journal of In-service Education* 31(2) 235-250.

Kennedy, M. (1998) *The relevance of content in inservice teacher education*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco

Kepler, L. (1996).*A year of hands-on science.* New York: Scholastic Professional Books**.**

King, M. B. & Newmann, F. M. (2000) Will teacher learning advance school goals? *Phi Delta Kappan*. 81(8), 576-580.

Koballa Jr., T. R. (1988). The determinants of female junior high school pupils' intentions to enrol in elective physical science courses in high school: testing the applicability of the theory of reasoned action. *Journal of Research in Science Teaching*, 25, 479–492

Koballa, Jr., T. R. (1995). Children's attitudes toward learning science. In S. Glyyn & R. Duit (Eds.), *Learning science in the schools* (Mawhah, NJ: Lawrence Erlbaum).

Kruger, C. & Summers, M. (1989) *An investigation of some primary teachers' understanding of changes in materials.* School Science Review, 71 (December) 17-27.

Layton, D., Jenkins, E., & Donnelly, J. (1994). Scientific and technological literacy. Meanings and rationales. An annotated bibliography. Leeds, UK: Centre for Studies in Science and Mathematics Education, University of Leeds

Lieberman, A. (1995, April). Practices that support teacher development: Transforming conceptions of professional learning. *Phi Delta Kappan, 76*(8), pp. 591-596

Little, A. (1995). *Multi-grade teaching: A review of research and practice* (Education Research Serial No. 12). London: Overseas Development Administration.

Little, J.W. (1990). The persistence of privacy: Autonomy and initiative in teachers' professional relations. *Teachers College Record* 91 (4), 509-536.

Little, J.W. (1993). Teachers' professional development in a climate of educational reform. *Educational evaluation and policy analysis.* 15(2), 129 - 151.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (2003). Designing professional development for teachers of science and mathematics education. Thousand Oaks, CA: Corwin.

Lund, T. (2005). The Qualitative-Quantitative Distinction: Some comments. *Scandinavian Journal of Education Research*, 49, 2, 115-132.

MacDonald, A. L., & Sherman, A. (2007). Pre-service teachers' experiences with a science education module. *Journal of Science Teacher Education*, *18*, 525-541.

MacNeil, D. J. 2004. "School- and Cluster-based Teacher Professional Development: Bringing Teacher Learning to Schools." Working Paper #1. Washington, DC: USAID, EQUIP1.

MacPhail, A., & Kinchin, G. (2004). The use of drawings as an evaluative tool: Students' experiences of sport education. *Physical Education and Sport Pedagogy, 9(1),* 87-108.

Magnusson, S., Borko, H. & Krajcik, J. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In Gess-Newsome, J. & Lederman, N.G. (eds.) *Examining Pedagogical Content Knowledge* (pp. 95-132). Dordrecht: Kluwer Academic Publishers.

Malone, A. & Smith, G. (2010) Developing Schools as Professional Learning Communities: The TL21 Experience. *US-China Education Review* v7 n9 p106-114

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), Centre of the study of testing, evaluation and educational policy

Matthews, M.R. (1994) *Science Teaching- the role of history and philosophy of science.* New York: Routledge.

Matthews, M.R. (1997) Editorial *Science and Education* 9(6), (p. 491-505)

Matthews, M.R. (ed.): (1998), *Constructivism and Science Education: A Philosophical Examination,* Kluwer Academic Publishers, Dordrecht.

Matthews, M.R. (2000). *Constructivism in Science and Mathematics Education.* Retrieved 6th October 2010, from http://wwwcsi.unian.it/educa/inglese/matthews.html

Matthews, P. (1992) Irish National Teachers' Organisation (INTO) *Primary science education in Ireland,* Dublin: INTO

Matthews, P (1993) Science in Primary Schools: a Review of Recent Research. *Studies in Education* (9) pp. 39 - 47

Matthews, P & McKenna, P (1996) Science Education: A Review of Recent Research. *Studies of Science Education,* 12 (2), 21-36

McDiarmid, G. W., Ball, D. L., & Anderson, C. (1989). Why Staying One Chapter Ahead Doesn't Really Work: Subject-Specific Pedagogy. In M. C. Reynolds (Ed.), Knowledge Base for the Beginning Teacher (pp. 193-205). Elmsford, NY: Pergamon Press.

McLaughlin, M.W., & Talbert, J.E. (1993) *Contexts that Matter for Teaching and Learning: Strategic Opportunities for meeting the Nation's Educational Goals* (Stanford: Stanford University Press)

Millar, R. & Osborne, J. (1998) *Beyond 2000: Science Education for the Future, a report with ten recommendations.*

Millar, R., & Osborne, J. F. (Eds.). (1998a). *Beyond 2000: Science Education for the Future*. London: King's College London.

Morris, R. (1990) *Science Education Worldwide.* UNESCO,Paris,

Muijs, D, and G. Lindsay. 2008. Where are we at? An empirical study of levels and methods of evaluating continuing professional development. *British Educational Research Journal* 34 (2):195-211.

Mulryan –Kyne, C (2005) The Grouping Practices of Teachers in Small Two-Teacher Primary Schools in the Republic of Ireland *Journal of Research in Rural Education, 20* (17)

Murchan, D., Loxley, A., Johnson, K. Quinn, M. & Fitzgerald, H (2005). *Evaluation of the Primary Curriculum Support Programme (PCSP).* Education Department, University of Dublin, Trinity College.

Murphy, C & Beggs, J (2002) Ten years of compulsory science: a study of children's attitudes. *Irish Educational Studies* **21**(2) 13-24

Murphy C, & Beggs J. (2003) Children's attitudes towards school science. *School Science Review*; 84 (308):109–16.

Murphy C, & Beggs J. (2005) *Primary Science in the UK: A scoping study.* London: Wellcome Trust.

Murphy C, Neil P, & Beggs J.(2007) Primary science teacher confidence revisited: ten years on. *Educational Research;* 49(4):415–30

Murphy C, & Smith G, (2012) The impact of a curriculum course on pre-service primary teachers' science content knowledge and attitudes towards teaching science. *Irish Educational Studies,* 31(1):77 - 95

Myers, R. E. & Fouts, J. T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. *Journal of Research in Science Teaching*, 29, 929–937.

National Competitiveness Council (NCC) (2009) Statement on Education and Training

National Council for Curriculum and Assessment (1990) Report of the Review Body on the Primary Curriculum, Dublin: NCCA.

National Council for Curriculum and Assessment (2005) *Primary curriculum review. Phase 1: Interim report for discussion*. Dublin: NCCA.

National Council for Curriculum and Assessment (2008). *Primary curriculum review. Phase 2: Final Report*. Dublin: NCCA.

O'Keeffe, C. (2007) *One Step Ahead – A Study of Teacher Confidence in Primary Science.* Masters in Education National University of Ireland, Maynooth

Oppenheim, A. N. (1992). *Questionnaire design, interviewing and attitude measurement.* London, UK: Pinter Publishers.

Organisation for Economic Cooperation and Development OECD (2009*), Teaching and Learning International Survey TALIS* (Paris)

Osborne, J. F. (1996). Beyond Constructivism. *Science Education*, 80(1), 53-82.

Osborne, J., Driver, R. & Simon, S. (1998) 'Attitudes to science: Issues and concerns', *School Science Review*, 79 (288): 27-33.

Osborne, J. F. & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum* (London: King's College London).

Osborne, R. & Freyberg, P. (1985) *Learning in Science. The Implications of Children's Science*. Heinemann Educational Books

Osborne, J. & Simon, S. (1996). Primary Science: past and future directions, *Studies in Science Education*, 26, 99-147.

Osborne, J., Simon, S. & Collins, S. (2003) Attitudes towards science: a review of the literature and its implications, *International Journal of Science Education*, 25(9), 1049–1079.

Osborne, J., Wadsworth, P., Black, P. & Meadows, J. (1994). *Primary SPACE Project Report: The Earth in Space*. Liverpool University Press.

Palmer, M. (2001) From Curriculum to Implementation – Primary Science and Teacher Development, *Irish Educational Studies*, Vol 20, p. 239-250

Patton, M. Q. (2002). Qualitative evaluation and research methods (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Peers, S. (2006). *Making a difference:* Primary Connections *Stage 3 Project Brief: 2006-2008.* Canberra: Australian Academy of Science

Peers, C.E., Diezmann, C.M. & Watters, J.J. (2003) Supports and Concerns for Teacher Professional Growth during the Implementation of a science Curriculum Innovation. *Research in Science Education*, Vol. 33, pp. 89-110

Pell, T. & Jarvis, T. (2001) Developing attitude to science scales for use with children of ages from five to eleven years, *International Journal of Science Education*, 23(8), 847–862.

Pell, T. & Jarvis, T. (2003) Developing attitude to science scales for use with primary teachers, *International Journal of Science Education*, 25(10), 1273–1295.

Piburn, M. D., & Baker, D. R. (1993). If I were a teacher . . . Qualitative study of attitude toward science. *Science Education, 77,* 393–406.

Piggot-Irvine, E (2006) Establishing criteria for effective professional development and use in evaluating an action research programme, *Journal of In-service Education*, 32, 4, pp. 477–496.

Primary Professional Development Service (2009). Overview of the Primary Professional Development Service: 2008/2009. Retrieved 11th Dec 2009 from http://ppds.ie/images/stories/LatestNews/ppdsannual%20report%202008_2009.pdf

Pring, R (2000) The 'False Dualism' of Educational Research, *Journal of Philosophy of Education*, 34, 2, pp. 247-260.

Pritchard, R, & McDiarmid, F (2005) Promoting Change in Teacher Practices: Investigating Factors which Contribute to Sustainability. Downloaded on 30 January 2011 from: http://www.merga.net.au/documents/RP492006.pdf

Quane, M (1998) An Historical Case Study in Curriculum Innovation: Henry Edward Armstrong – William Mayhowe Heller and the implementation of Elementary Science in the Irish National System from 1900-1922

Radford, D. (1998) Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science Teaching,* 35, 1 73-88

Ramsden, J. (1998) Mission impossible?: can anything be done about attitudes to science?, *International Journal of Science Education*, 20(2), 125–137

Reid**,** N. **(***2006***)** Thoughts on *Attitude* Measurement, Research in Science and Technological Education, 24(1), 3-27.

Rennie, L. J., Parker, L. H. & Hutchinson (1985) *The effect of inservice training on teacher attitudes and primary school science classroom climates* Perth: University of Western Australia, Department of Education.

Riding, P. (2001) "Online Teacher Communities and Continuing Professional Development" *Teacher Development,* 5,(3), pp283-296.

Robson, C. (2002) *Real world research, Oxford, England:* Blackwell publishing.

Rocard Report (2007). *Science Education Now: a renewed pedagogy for the future of Europe European commission*

Rocco TS, Bliss LA, Gallagher S & Perez-Prado A (2003) Taking the next step: mixed methods research in organizational systems, *Information Technology, Learning, and Performance Journal* 21(1): 19 - 29.

Rose, J. & Reynolds, D. (2006) *Teachers' Continuing Professional Development: A New Approach*. Paper presented at 20th Annual World International Congress for effectiveness and Improvement.

Royal Irish Academy (2005) School Science Infrastructure: Can Ireland Deliver?

Russell, T., Bell, D., McGuigan, L., Qualter, A., Quinn, J. & Schilling, M. (1992) teachers' conceptual understanding in science, in: L.D. Newton (Ed.) *Primary Science* (Clevedon, Multilingual Matters)

Schebeci, R. A. (1984) Attitudes to science: an update, *Studies in Science Education,* 11, 26–59.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books

Selwyn, N. Boraschi, D. And Ozkula, S (2009) Drawing digital pictures: an investigation of primary pupils' representations of ICT and schools. *British Educational Research Journal,* 35 (6) 909 – 928

Shanker, A. (1996). Quality assurance: What must be done to strengthen the teaching profession. *Phi Delta Kappan, 78*(3), 220-224.

Scottish Executive Education Department (2000) *A Teaching Profession for the 21st Century*.
Edinburgh: Scottish Executive.

Shulman, L.S. (1986) Those who understand: Knowledge growth in teaching, *Educational Researcher, 15*(2), 4-14.

Shulman, L.S. (1987) *Knowledge and teaching*: *foundations of the new reform.* Harvard Educational Review 7, 1-22.

Siegel, M.A., & Ranney, M.A. (2003). Developing the Changes in Attitude about the Relevance of Science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching 40* (8), 757-775.

Sigsworth, A. & Solstad, J. (2001) Making Small Schools Work A Handbook for Teachers in Small Rural Schools UNESCO International Institute for Capacity Building in Africa.

Simpson, R. D., & Oliver, J. S. (1985). Attitude toward science and achievement motivation profiles of male and female science pupils in grades six through ten. *Science Education*, 69,
511–526.

Simpson, R. D. & Oliver, J. S. (1990). A summary of the major influences on attitude toward and achievement in science among adolescent pupils. *Science Education*, 74, 1–18.

Simpson, R.D. & Talton, E.L. (1986) Relationships of Attitudes Towards Self, Family and School with Attitude Toward Science among Adolescents. *Science Education* Vol. 70, No. 4, pp. 365-374.

Simpson, R.D. & Troot, K. (1982) Influences on the commitment to and learning of science among adolescent pupils. *Science Education, 66 (5),* 763-781.

Smith, G (1999) *Science, Technology, and Society in Transition year: A Pilot Study,* unpublished M.Sc. thesis, Trinity College Dublin

Smyth, E. & Hannan, C. (2002). *Who chooses science? Subject choice in secondlevel schools*. Dublin: Liffey Press/ ESRI.

Solomon, J. (1995) 'Constructivism and quality in science education', in P. Murphy, M. Selinger, J. Bourne & M. Briggs (eds.) Subject Learning in the Primary Curriculum, London & New York: Open University Press.

Solomon, J. & Aikenhead G.S.(1994) *STS education: International perspectives on reform*. New York: Teachers College Press.

Sparks, D. & Loucks-Horsley, S. (1990). *Models of staff development.* In W.R. Houston (ed.), *Handbook of research on teacher education.* New York: Macmillan.

Stenhouse, L. (1975). *An Introduction to Curriculum Research and Development*. London: Heinemann.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change, 7*(4), 221-258.

Sugrue, C. (2002). Irish teachers' experiences of professional learning: Implications for policy and practice. *Journal of In-Service Education,* 28(2) 311-338.

Sugrue, C., Morgan, M., Devine, D., Raftery, D. (2001), *Policy and Practice of Professional Development for Primary and Post-Primary Teachers in Ireland : A Critical Analysis,* (unpublished).

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Summers, M. & Kruger, C. (1992) Research into English primary school teachers' understanding of the concept of energy. *Evaluation and Research in Education*, Vol. 6, pp. 95-111

Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Thousand Oaks, CA: Sage.

Task Force on the Physical Sciences. (2002). Report and recommendations of the task force on the physical sciences. Available online at http://www.education.ie/servlet/bloservelet/physical_sciences_report.pdf

Teaching Council of Ireland (2009) Learning to teach and its implications for the continuum of teacher education :A nine-country cross-national study. Accessed on 8th November, 2011 from http://www.teachingcouncil.ie

Teaching Council of Ireland (2010) Draft Document on Continuum of Teacher Education Background Report :Teacher Education in Ireland and Internationally. Accessed on 25th March, 2011 from http://www.teachingcouncil.ie

Teaching Council of Ireland (2011) Initial Teacher Education: Criteria and Guidelines for Programme Providers. Accessed on 2nd January 2012 from http://www.teachingcouncil.ie

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science, in Gabel, D. L., ed. Handbook of research on science teaching and learning. MacMillan Publishing Co., NY

Van Driel, J.H., De Jong, O., & Verloop, N. (2002). The development of pre-service chemistry teachers' PCK. *Science Education, 86,* 4, 572-590.

Varley, J., Murphy, C. & Veale, Ó. (2008) *Science in primary schools: Phase 1.Research commissioned by NCCA, final report*. Dublin: NCCA.

Varley, J., Murphy, C. & Veale, Ó. (2009) *Science in primary schools: Phase 2. Research commissioned by NCCA, final report*. Dublin: NCCA.

Vescio, V., Ross, D., & Adams, A. (January, 2006). Review on professional learning communities: What do we know? Paper presented at the NSRF Research Forum. Retrieved December 14, 2008, from http://www.nsrfharmony.org/research.vescio_ross_adams.pdf

Waldron, W., Pike, S., Greenwood, R., Murphy, C.M., O' Connor, G., Dolan, A., Kerr, K. (2009). *Becoming a teacher: Primary pupil teachers as learners and teachers of history, geography and science: An all-Ireland study.* Standing Conference on Teacher Education North and South (SCoTENS).

Walsh, E. (1999) Science for All, *The Irish Journal of Education*, Vol. 30, p. 3-21

Walsh, T (2007) The Revised Programme of Instruction, 1900-1922, *Irish Educational Studies* 26, 2 127-143

Weinburgh, M. (1995). Gender differences in pupil attitudes toward science: A meta analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32* (4), 387-398.

Wilson, S.M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education, 24,* 173-209.

Woodward, C. and Woodward, N. (1998) Girls and science: does a core curriculum in primary school give cause for optimism? *Gender and Education,* 10 (4), 387- 400

Woolnough, B. (1994). *Effective science teaching* (Buckingham: Open University Press).

Wragg EC, Bennett SN, & Carré, CG. (1989) Primary teachers and the National Curriculum. *Research Papers in Education*, 4(3), 17-37.

Yager, R.E.(1983) The importance of terminology in teaching K-12 science. *Journal of Research in Science Teaching.* 20 (6) 577-588.

Yager, R.E. (1996) *Science / Technology / Society. As a reform in Science Education* Albany: State University of New York Press.

Yager, R.E. & Penich, J.E.(1984) *Perceptions of four age groups towards science classes, teachers and the value of science.* Iowa city, I.A. The University of Iowa.

Appendix A - Reflection on the workshops

Reflections on the Workshops

Name: ___________________________ ***Date:*** _____________

Strengths of the Workshop

Shortcomings/Weakness of the Workshop

Suggestions for the Future

Appendix B: Teacher questionnaire (pre/post)

Teacher Attitudes to Science Questionnaire

Background Information

1. Your Gender:

   Male ☐ Female ☐

2. No of years teaching: …………………………………………..

3. What is your highest qualification in science?

   Junior/Inter Cert ☐ Leaving Cert ☐ Degree ☐

4. Science subjects studied for Leaving Certificate: (Please specify)

   ☐

5. As a teacher have you attended any professional development courses in science education? (e.g. In-service, third level etc…)

   Yes ☐ No ☐ (If yes please give details)

   ☐

6. How many teachers are in your school?

   1 ☐ 2 ☐ 3 ☐ >3 ☐

7. Approximately how many pupils in your school?

   <50 ☐ 50 -100 ☐ 100 -150 ☐ >150 ☐

8. How much time do you spend per week teaching science?

<1hr ☐ 1-2hr ☐ 2-3hr ☐ >3hr ☐

9. Do you feel you have enough resources in your school to teach science effectively?

Yes ☐ No ☐

(If no please give details)

Assessment Methods in Science Teaching

10. Are you familiar with the term ‘Assessment for Learning’

Yes ☐ No ☐

(If yes please give details of how and when you came across it)

11. Please place an **X** beside the statement that best describes assessment as you use it in your classroom

{ } Assessment is a test given to pupils in order to give grades and Inform parents and administrators

{ } Assessment is a tool that helps the teacher and pupils to enhance teaching and learning

{ } Assessment is a test a teacher gives to pupils at the end of a topic or the end of a term

{ } Assessment is used to ‘place’ a pupil in the class

Teaching Across the Primary Curriculum

11. Some teachers are more confident in their knowledge and teaching skills in some areas of the curriculum than others. Please give an estimate of how you feel in general about teaching each of the following subjects

1 = very low in confidence (I require support with this)

2 = low confidence

3 = average confidence

4 = high confidence

5 = very high confident (I have no problem with this)

(Please circle the appropriate code number on the five point scale)

English	**1**	**2**	**3**	**4**	**5**
Irish	**1**	**2**	**3**	**4**	**5**
History	**1**	**2**	**3**	**4**	**5**
Geography	**1**	**2**	**3**	**4**	**5**
Maths	**1**	**2**	**3**	**4**	**5**
Science	**1**	**2**	**3**	**4**	**5**
ICT	**1**	**2**	**3**	**4**	**5**

Confidence in Teaching Content of Primary Science Curriculum

12. How confident do you feel that you have the knowledge needed to help pupils develop an understanding of each of the following? (quoted from "Social Environmental and Scientific Education" primary science curriculum)

1 = very low in confidence (I require support with this)

2 = low confidence

3 = average confidence

4 = high confidence

5 = very high confident (I have no problem with this)

(Please circle the appropriate code number on the five point scale)

	Living Things					
(a)	Structure of some of the body's major internal and external organs	1	2	3	4	5
(b)	Reproductive systems of both males and females and physical changes in both	1	2	3	4	5
(c)	Some of the factors that affect plant growth	1	2	3	4	5
(d)	Some of the ways plants reproduce	1	2	3	4	5
	Energy and Forces					
(e)	The refraction of light using mirrors	1	2	3	4	5
(f)	The splitting and mixing of light	1	2	3	4	5
(g)	How sound travels through materials	1	2	3	4	5
(h)	How sound is produced	1	2	3	4	5
(i)	Sources of heat	1	2	3	4	5
(j)	Transfer of heat (conduction, convection and radiation)	1	2	3	4	5
(k)	Electrical current and construction of simple circuits, (e.g. lamps, buzzers, motors)	1	2	3	4	5
(l)	Electrical energy	1	2	3	4	5
(m)	Magnets and their push and pull effects	1	2	3	4	5
(n)	The making of magnets	1	2	3	4	5
(o)	The effect of friction on movement	1	2	3	4	5
(p)	The force of gravity	1	2	3	4	5
	Materials					
(q)	The effects of heating and cooling on a range of solids, liquids and gases	1	2	3	4	5
(r)	How a wide range of materials may be changed by mixing	1	2	3	4	5
	Environment					
(s)	The effects of human activity on the environment	1	2	3	4	5
(t)	The need to conserve resources	1	2	3	4	5

13. Is there any part of the science curriculum that you don't teach?

Yes ☐ No ☐

(If yes please give details)
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………

Confidence in Developing Pupils' Scientific Skills

14. Please rate how confident you feel (1-5) in helping pupils to develop the following scientific skills?

1 = very low in confidence (I require support with this)

2 = low confidence

3 = average confidence

4 = high confidence

5 = very high confident (I have no problem with this)

(Please circle the appropriate code number on the five point scale)

	Pupils' Scientific Skills					
(a)	Identifying relevant questions to investigate	1	2	3	4	5
(b)	Recognising their observation skills	1	2	3	4	5
(c)	Making and testing hypotheses	1	2	3	4	5
(d)	Recording and presenting data using a variety of methods	1	2	3	4	5
(e)	Interpreting data and offer explanations	1	2	3	4	5
(f)	Realising an investigation is unfair if relevant variables are not controlled	1	2	3	4	5
(g)	Understanding how science might affect their lives	1	2	3	4	5

15. How would you rate your confidence from 1-5 in developing pupils' Design and Make skills? (e.g. designing and making a bridge or lighthouse)

1 = very low in confidence (I require support with this)

2 = low confidence

3 = average confidence

4 = high confidence

5 = very high confident (I have no problem with this)

(Please circle the appropriate code number on the five point scale)

	Pupils' Design-and-make Skills					
(a)	Pupils exploring skills	1	2	3	4	5
(b)	Pupils planning skills	1	2	3	4	5
(c)	Pupils making skills	1	2	3	4	5
(d)	Pupils evaluating skills	1	2	3	4	5

Your Own Science Teaching Skills

16. How would you rate your confidence from (1-5) in the following teaching skills?

1 = very low in confidence (I require support with this)

2 = low confidence

3 = average confidence

4 = high confidence

5 = very high confident (I have no problem with this)

(Please circle the appropriate code number on the five point scale)

	Teaching Skills					
(a)	Using questioning as a tool in science teaching	1	2	3	4	5
(b)	Explaining science concepts to pupils	1	2	3	4	5
(c)	Encouraging pupils to try out their own ideas in investigations	1	2	3	4	5
(d)	Encouraging pupils to think for themselves	1	2	3	4	5
(e)	Organising and delivering practical work	1	2	3	4	5
(f)	Deciding the science skills to be developed in an activity	1	2	3	4	5
(g)	Using ICT to enhance teaching and learning in science	1	2	3	4	5
(e)	Assessing practical work	1	2	3	4	5

Teaching Methodologies in Science

17. How often do you use the following teaching methodologies with pupils in science?

Frequency:

1 = not at all   2 = rarely   3 = sometimes   4 = frequently   5 = very frequently

(Please circle the appropriate code number on the five point scale)

		Frequency
(a)	Cooperative learning	1 2 3 4 5
(b)	Predict Observe Explain (P-O-E)	1 2 3 4 5
(c)	Concept Cartoons	1 2 3 4 5
(d)	Concept-Mapping	1 2 3 4 5
(e)	Discussion	1 2 3 4 5
(f)	Use children's ideas to start the topic	1 2 3 4 5
(g)	Using hands-on experience	1 2 3 4 5
(h)	Using ICT	1 2 3 4 5
(i)	Written feedback comments on assessment work	1 2 3 4 5

18. How useful do you find these teaching methodologies?

1 = not very useful   2 = not useful   3 = useful   4 = very useful   5 = extremely useful

(Please circle the appropriate code number on the five point scale)

		Usefulness
(a)	Cooperative learning	1 2 3 4 5
(b)	Predict Observe Explain (P-O-E)	1 2 3 4 5
(c)	Concept Cartoons	1 2 3 4 5
(d)	Concept-Mapping	1 2 3 4 5
(e)	Discussion	1 2 3 4 5
(f)	Use children's ideas to start the topic	1 2 3 4 5
(g)	Using hands-on experience	1 2 3 4 5
(h)	Using ICT	1 2 3 4 5
(i)	Written feedback comments on assessment work	1 2 3 4 5

Have you developed any resources for the teaching of science?

Yes ☐ No ☐

If yes please give details

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………

Are there areas of the science curriculum which you find challenging? If the answer is yes please give reasons why

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………

What are your concerns regarding teaching science in your school?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………

Thank you very much for patience and time

Appendix C: Pupil questionnaire (pre/post)

Questionnaire on Pupils' Attitudes to Science

Ask your teacher if you need help filling this in

I am a ……………………………………………………………………(boy/girl)

My class is …………………………………………………………..

My school is………

When you come to a question, put an X on the smiley face that is closest to your opinion. Try the following examples.

	Yes	**Not Sure**	**No**
1. I like watching television	☺	😐	☹
2. I like dancing	☺	😐	☹

You are now ready to start

Please turn over when your teacher tells you

Remember to ask your teacher if you need help filling this in

What I think about being in school:	**Yes** ☺	**Not sure** 😐	***No*** ☹
1. I like school	☺	😐	☹
2. I'm happy at school	☺	😐	☹
3. I work as hard as I can in school	☺	😐	☹
4. I find school interesting	☺	😐	☹
5. I enjoy doing school-work	☺	😐	☹
6. I enjoy working with my friends at school	☺	😐	☹
7. I enjoy working on my own	☺	😐	☹
8. I enjoy using the computer	☺	😐	☹
9. I enjoy doing science experiments	☺	😐	☹

I enjoy learning about…	**Yes** ☺	**Not sure** 😐	**No** ☹
1. Insects and mini-beasts	☺	😐	☹
2. Magnets	☺	😐	☹
3. Saving energy and recycling	☺	😐	☹
4. How the human body works	☺	😐	☹
5. How sound travels	☺	😐	☹
6. Solids, liquids and gases	☺	😐	☹
7. How we heat our homes	☺	😐	☹
8. Materials we use for making things such as wood, metal and plastic	☺	😐	☹
9. Plants and how they grow	☺	😐	☹

I enjoy learning about…	**Yes** ☺	**Not sure** 😐	**No** ☹
10. How machines work and move	☺	😐	☹
11. How to look after the environment	☺	😐	☹
12. What happens when you mix things together	☺	😐	☹
13. Animals from around the world	☺	😐	☹
14. Electricity, batteries, bulbs and switches	☺	😐	☹
15. Inventions and discoveries	☺	😐	☹
16. What happens to things when you heat or cool them	☺	😐	☹
17. How to keep fit and healthy	☺	😐	☹
18. Light, mirrors and shadows	☺	😐	☹

Remember to put an X on the smiley face that is closest to your opinion.

What I enjoy in science experiments: I enjoy science experiments when….	***Yes*** ☺	**Not sure** 😐	**No** ☹
1. I do an experiment by myself	☺	😐	☹
2. I do an experiment with my friends	☺	😐	☹
3. I watch my teacher doing an experiment	☺	😐	☹
4. I plan and do my own experiment	☺	😐	☹
5. The teacher tells me what to do	☺	😐	☹
6. My teacher explains things to the class	☺	😐	☹
7. Finding out why the experiment worked	☺	😐	☹
8. When we go outside the classroom to do science	☺	😐	☹
9. I choose my own equipment	☺	😐	☹

What I enjoy in science lessons: I enjoy science when….	***Yes*** ☺	**Not sure** 😐	**No** ☹
10. I use computer programmes in science class	☺	😐	☹
11. I use the internet at school to find out about science	☺	😐	☹
12. We watch science programmes at school	☺	😐	☹
13. I fill in my workbook/worksheet	☺	😐	☹
14. I write about something I have done in science class	☺	😐	☹
15. I design and make my own things	☺	😐	☹
16. I read my science schoolbook	☺	😐	☹

Put an X on the smiley face that is closest to your opinion.

What I think about science:	**Yes** ☺	**Not sure** 😐	**No** ☹
1. School science is easy	☺	😐	☹
2. School science is interesting	☺	😐	☹
3. I like science better than other subjects	☺	😐	☹
4. I look forward to science lessons	☺	😐	☹
5. I am looking forward to learning science in secondary school	☺	😐	☹
6. When scientists give an explanation about something it is always true	☺	😐	☹
7. You have to be clever to do science	☺	😐	☹
8. Science is just too difficult	☺	😐	☹
9. TV, telephones and radio all need science	☺	😐	☹

Think about your science class in school. What was your favourite science lesson.

____

____

____

____

____

Write down what you did in your favourite science lesson

____

____

____

____

____

_

Why did you enjoy it?

____

____

____

____

____

_____

Think about science class in school. Describe a school science lesson that you didn't enjoy.

____

____

____

____

____

Why didn't you enjoy it?

____

____

____

____

____

Think about how your class does science in school. Draw a picture of yourself and your class doing science at school.

Great work well done and thank you very much

Appendix D: Interview questions for teachers

Interview Questions for Teachers

Since attending the WSSP

Questions on Classroom Practice

- To what extent have you introduced new science strategies (methodologies) into your science lessons
- To what extent has your view of teaching science changed as a result of your involvement in the project?
- Do you feel as confident teaching science now than before the project?
- Have you observed any changes in your pupils' attitudes to science since your participation in the project?
- What barriers, if any, keep you from implementing new science strategies into your science lessons

Questions on Professional Development

- What did you want to achieve from your involvement in the project?
- What did you gain most from your involvement in the project?
- Have your views on the purposes of professional development changed since you started this project?
- What do you think are the characteristics of effective professional development?
- Where there any barriers associated with this professional development programme?

Appendix E: Interview questions for pupils

Interview Questions for Pupils (pre/post intervention)

The pupils were asked following questions pre- and post-intervention. The order of questions and probes varied from interview to interview, however the interviewer tried to keep to the general framework as much as he could.

Do you like doing science in school?

Probe - Why /Why not?
- What things do you like about science in school?
- What kinds of things do you not like about science in school?

I am an alien from another planet, I am meeting you all for the first time and I know nothing about science. Could you tell me what you do in your science lesson?

Probe - What would you be doing?
- What would the teacher be doing?
- Does your teacher read out of a book?
- Does your teacher demonstrate experiments?
- Do you do experiments?

Can you tell me what you did in your last science lesson?

Probe - What did you do during this lesson?
- Did you like this lesson?
- Did you carry out an experiment during this lesson?
- What did you like/not like about this lesson?
- What was your favourite part of the lesson?
- What did you learn in this lesson?

When was the last time you did an experiment in a science lesson?

Probe - What did you do?
- Did you like doing it?

- Do you do experiments yourself or does the teacher show you?
- Would you like to do more experiments?

Do you ever work in groups in science lessons?

Probe - What do you like about working in groups (if yes)?
- Would you like to work in groups (if no)?
- What kinds of things have you done in groups?
- Do you have special jobs to do when you are in groups?
- Do you work in groups in any other lessons?

Do you have a textbook for science in school?

Probe - do you like your textbook?
- What do you like/dislike about it?
- Have you done any of the experiments in your science textbook?
- Does your teacher read from the textbook in class?
- Do you read from the textbook in class?
- Do you like reading from the book?

Do you do much writing during science lessons?

Probe - Do you like writing?
- Does the teacher put writing on the board during science lessons?

If I was going to be your teacher next year, what kind of things would you like me to do in science?

Probe - What things would you like to do more of?
- What things would you like to do less of?

Appendix F: Statements from science curriculum

Statements taken from the Primary Science Curriculum

Statements relating to Strand: Energy and Forces Please state whether the following statement is True of False	**True**	**False**
Gravity only acts on objects when they are falling		
Friction only acts on moving objects		
Heavy things fall to the ground quicker than light things		
Objects which are sitting still have no forces activity on them		
The moon is luminous		
Sound can only travel through air, not solid or liquid		
Less current returns to the battery when it passes through say a bulb (it is used up)		
Current flows from battery to bulb but not from bulb back to battery		
If an object is at rest no forces are acting on it		
Wood floats and metal sinks		
All metals are attracted to a magnet		
Heat travels from a cold body to a hot body		
If two objects have the same temperature they have the same amount of heat		

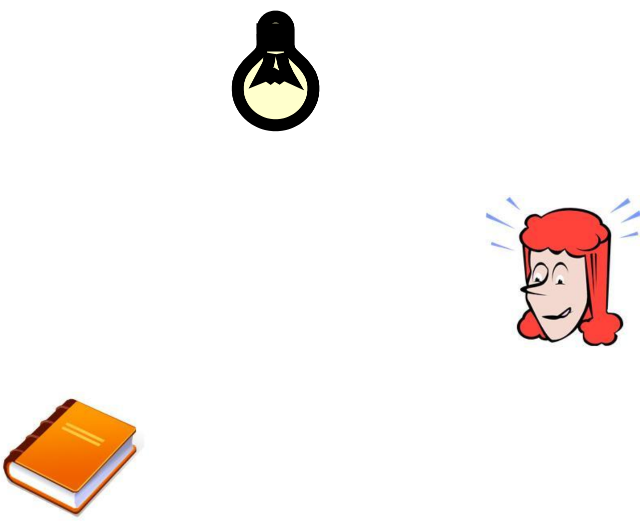
Statements relating to Strand: Living Things (Plants)
Which of the following are plants (Tick)

	Yes	No
A tree in the ground		
A potato growing in the ground		
A thistle growing in the ground		
A daisy growing in the ground		

Statements relating to Strand: Living Things (Animals)
Which of the following are animals (Tick)

	Yes	No
A fish in a pond		
A dog found around the house		
A human being		
A common household fly		
An elephant		
A snake		
A spider		

Diagram below shows a book with a bright light above it. You are standing to one side of table. Draw lines with arrows on the diagram to show where the light goes.



Appendix G: Topics for future workshops

WSSP

Workshops 2008/2009

Possible topics for future workshops – please nominate in order of personal preference (1 – 11) topics you would like to deal with during the course of workshops 08/09.

TOPIC	PREFERENCE
Explanation of Scientific concepts	
Electricity/Magnetism	
How pupils learn (pupil preconceptions)	
Forces	
Heat	
Living things	
Sound/light	
Use of ICT in science	
Carrying out Investigations in science (fair test)	
Sharing ideas and resources	
Active teaching methodologies in science	
Other	

Appendix H: Teacher reflection template (end Year One)

Western Seaboard Science Project

Thinking back on your engagement with WSSP so far please complete the following.

What have been the greatest benefits for you personally as a result of your work with WSSP

Please provide evidence to support your answer

What benefits have there been for your Pupils/School as a result of your work with WSSP?

Please provide evidence to support your answer

Has your confidence in teaching science changed since your involvement with WSSP?

Has your teaching approach to science changed since your involvement with WSSP?

Please feel free to add any additional comments and/or recommendations regarding WSSP

Thank you for taking the time to complete this survey. We value and appreciate your comments and opinions

Appendix I: Information letter to schools

25th February, 2008

Dear

By now you should have received a letter from Brian Murray from the American Partnership welcoming you and your school to the 'rural primary schools science project', jointly funded by the American Partnership and the Department of Education and Science.

I would like to introduce myself to you, my name is Greg Smith and I will be coordinating the project on behalf of St Patrick's College Dublin. I am hoping to visit all the schools and meet all of the teacher/s involved in the project before you break for the Easter holidays. I would like to discuss; the aims and objectives of the project, funding and purchasing of resources, any needs and concerns of teacher/s. I will phone you later this week or early next week to arrange a suitable time to visit your school.

On behalf of Dr. Kilfeather (project leader) and myself I would like to welcome you to the project and I am confident that your school - teacher/s and pupils alike will benefit immensely from their participation in the project.

I am very much looking forward to meeting with you soon.

With kind regards

Greg Smith

Appendix J: Consent letter to parents/guardians

Western Seaboard Science Project

Dear Parent/ Guardian,

We are working on a project funded by the Irish American Partnership and the Department of Education and Science to review science in primary schools. We hope to find out about children's engagement in and attitudes towards primary school science and what, if any changes need to be made. St. Joseph's National School has kindly agreed to take part in the study. We are writing to seek your consent for your child's involvement in this project.

As part of this study primary school children from 4th to 6th class across 15 small rural schools in the West of Ireland will complete a questionnaire about their attitudes towards science (before and after project). We would be delighted if your child could be involved in this important study. We are seeking your permission to allow your child to complete a questionnaire regarding their attitudes towards science. Its average completion time is 20-30 minutes.

The researcher heading this project is a qualified and experienced school teacher. No child will be identifiable by name, class or school on anything that is written about this project. Only the research team will have access to any notes made.

If you wish to ask further questions about the project, please contact the research coordinator, Greg Smith at St. Patrick's College, Drumcondra, Dublin 9 (Tel: 01 884 2000, mobile 0876635123).

- Your child does not have to participate in the study.

- Your child can choose to withdraw from the study at any time.

Many thanks,

Please note that the names of participating schools and pupils will be confidential and will not be revealed or identifiable in any publications.

Greg Smith

Permission Slip. Please sign and return to your child's class teacher by [date]

I agree/ do not agree* that ________________can fill out a questionnaire during their usual science class.

Signature of parent/ guardian ________________________________ Date ___________

Appendix K: Tables of boys' and girls' attitudes to various aspects of school science

Table 8.9: Gender attitudes about school (before and after intervention)

	Male				Female			
	Pre Intervention		**Post Intervention**		**Pre Intervention**		**Post Intervention**	
	Mean	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**
What I think of school								
I like school	2.13	0.786	2.18	0.781	2.53	0.669	2.50	0.703
I'm happy at school	2.59	0.578	2.60	0.613	2.77	0.486	2.76	0.799
I work hard at school	2.76	0.476	2.69	0.525	2.81	0.465	2.84	0.387
I find school interesting	2.31	0.685	2.24	0.727	2.46	0.646	2.39	0.716
I enjoy doing school work	1.84	0.781	1.87	0.771	2.06	0.766	2.25	0.753
I enjoy working on my own	2.14	0.839	2.11	0.769	2.30	0.759	2.18	0.815
I enjoy working with friends at school	2.81	0.481	2.89	0.338	2.04	0.306	2.89	0.355

** $p < .01$ significant difference paired *t*-test.

Table 8.10: Gender attitudes about school science (before and after intervention)

	Male				Female			
	Pre Intervention		**Post Intervention**		**Pre Intervention**		**Post Intervention**	
	Mean	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**
What I think of science at school								
School science is interesting	2.63	0.608	2.68	0.581	2.68	0.597	2.74	0.532
School science is easy	2.36	0.508	2.48	0.656	2.44	0.700	2.43	0.655
I like science better than other subjects	2.13	0.833	2.31	0.748	2.21	0.769	2.08	0.765
I look forward to science lessons	2.64	0.581	2.59	0.650	2.56	0.608	2.62	0.624
What I think about science								
You have to be clever to do science	1.88	0.864	1.70	0.838	1.66	0.797	1.47	0.702
Science is just too difficult	1.41	0.651	1.29	0.545	1.43	0.655	1.30	0.590

** $p < .01$ significant difference paired *t*-test.

Table 8.11: Gender attitudes about experiments (before and after intervention)

	Male				Female			
	Pre Intervention		**Post Intervention**		**Pre Intervention**		**Post Intervention**	
	Mean	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**
I enjoy science experiments								
I do experiment myself	2.12	0.792	2.11	0.835	2.25	0.763	2.07	0.872
I do experiment with friends	2.70	0.672	2.77	0.546	2.80	0.561	2.86	0.440
I watch the teacher doing experiment	2.30	0.881	2.34	0.839	2.35	0.798	2.54	0.785
I plan my own experiment	2.30	0.773	2.21	0.795	2.37	0.743	2.24	0.818
The teacher tells me what to do	2.40	0.765	2.24	0.848	2.44	0.742	2.34	0.748
Finding out how experiment worked	2.28	0.861	2.67**	0.611	2.38	0.440	2.80**	0.859
Go outside classroom to do science	2.73	0.535	2.79	0.509	2.77	0.521	2.01	0.524
I choose my own equipment	2.44	0.730	2.45	0.709	2.47	0.681	2.38	0.747
I design and make my own things	2.56	0.740	2.62	0.668	2.55	0.723	2.64	0.665

** $p < .01$ significant difference paired *t*-test.

Table 8.12: Gender attitudes about science content (before and after intervention)

	Male				Female			
	Pre Intervention		**Post Intervention**		**Pre Intervention**		**Post Intervention**	
I enjoy learning about	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**
Insects and mini-beasts	2.37	0.780	2.16**	0.803	1.92	0.838	2.06	0.795
How human body works	2.60	0.637	2.57	0.768	2.58	0.637	2.53	0.834
Plants and how they grow	2.61	0.586	2.27**	0.775	2.70	0.538	2.56	0.811
Different animals around the world	2.54	0.689	2.67	0.639	2.61	0.588	2.47	0.687
How to look after environment	2.43	0.697	2.43	0.749	2.55	0.646	2.44	0.840
Keeping fit and healthy	2.50	0.690	2.50	0.732	2.52	0.670	2.51	0.743
Saving energy and recycling	2.33	0.743	2.25	0.789	2.37	0.747	2.27	0.886
How sound travels	2.52	0.700	2.61	0.669	2.60	0.615	2.47	0.887
Magnets	2.22	0.807	2.16	0.848	2.47	0.703	2.50	0.745
Electricity, batteries, bulbs & switches	2.76	0.507	2.75	0.595	2.26	0.765	2.28	0.810
Heating and cooling things	2.45	0.655	2.33	0.743	2.70	0.564	2.65	0.591
Light, mirrors and shadows	2.77	0.503	2.82	0.487	2.82	0.474	2.85	0.435
How machines work and move	2.75	0.514	2.60	0.637	2.78	0.513	2.77	0.535
How we heat our homes	2.59	0.662	2.50	0.742	2.42	0.709	2.38	0.725
Inventions and discoveries	2.76	0.480	2.73	0.535	2.60	0.615	2.65	0.605
Materials we use to make things	2.39	0.733	2.47	0.700	2.58	0.630	2.56	0.721
Solids, liquids and gases	2.70	0.550	2.68	0.631	2.81	0.479	2.74	0.549
When you mix things together	2.34	0.755	2.24	0.805	2.50	0.681	2.53	0.669

** $p < .01$ significant difference paired *t*-test.

Appendix L: Science equipment in schools

Science Equipment in School

Name of School: ………………………………………………….

Could you please conduct an audit of science resources already in school and return to me as soon as possible – this enables me to order in bulk, keeping the costs down

Energy and Forces Equipment	**Numbers we have in the school at present** **(filled in by teacher)**	**To be filled in by Greg**
LIGHT		
Torches		
Plastic mirrors (flat and curved)		
Prism		
Colour filter paper		
Colour paddles		
kaleidoscope		
Overhead projector		
SOUND		
Tuning folks		
slinky		
Sound boxes		
Tape recorder		
Musical instruments		
Drinking straws		
Rubber bands various thickness		

Energy and Forces Equipment	**Numbers we have in the school at present** **(filled in by teacher)**	**To be filled in by Greg**
Magnets/electricity		
Compasses		
Selection of magnets (please specify – marbles, horse shoe, disc and bar)		
Selection of metal discs		
Iron filings		
Reel of single core wire		
Wire strippers/cutters		
Type C single battery holder		
Type C double battery holder		
Bulb holders		
Screwdrivers		
2.5V bulbs		
Crocodile clips/leads		
Buzzers		
Motors		
Motor clips		
Selection of bulbs 1.5V, 3V		
Balloon pump		
Paper chips (box)		

Forces	**Numbers we have in the school at present** **(filled in by teacher)**	**To be filled in by Greg**
Plastic tubing		
Construction sets (mecano, pulleys, wheels)		
Wood blocks		
Wheeled toys		
Sandpaper		
Marbles		
Different		
Spools (for pulleys)		

Heat/Materials	**Numbers we have in the school at present** **(filled in by teacher)**	**To be filled in by Greg**
Forehead thermometer		
Spirit thermometer		
Standard window thermometer		
LCD thermometer		
Funnels		
Plastic sieves with metal meshes		
Measuring scoops and spoons		
Filter paper		

Living things Equipment	**Numbers we have in the school at present (filled in by teacher)**	**To be filled in by Greg**
Magnifying glasses		
Pooters		
Identification keys		
Petri dishes		
Insect traps		
Box plastic gloves		
Clip boards		
Large white/plastic sheet		
Metal spoons		
Containers for planting seeds		
Sieves (pond work)		
White plastic basin		
Quadrats		

Measuring Equipment	**Numbers we have in the school at present (filled in by teacher)**	**To be filled in by Greg**
Measuring tapes		
Measuring cylinders		
Measuring jugs		
Measuring spoons		
Metre sticks		
Calibrated syringes		
Spring balance (Newton meter)		
Kitchen scales		
Set of masses (weights)		
Stopwatches		

Other Useful Resources	**Title etc…** **(filled in by teacher)**	**To be filled in by Greg**
Science CDs or DVDs		
Reference Books		
Worksheets/Templates		
Useful websites		
Other		