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The Policy Implementation Process
in
The Upper Secondary Education System (Senior Cycle) and
Videregående Skolen
in
Science and Mathematics in the Republic of Ireland and
The Kingdom of Norway
From 1960-2005

Geraldine Mooney Simmie

Thesis submitted for a Ph.D. degree

University of Dublin
Trinity College
Department of Education

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Geraldine Mooney Simmie

June 2009.

DECLARATION

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Geraldine Mooney Sinnie
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Summary

The substantive issue at the heart of this thesis is identifying the key changes in science and mathematics mandated by the state, in upper secondary academic education, and seeing the extent to which these are translated into school praxis, through the perspectives of management and teachers and, of equal importance, through the organisational and structural reforms taking place at the level of the school. The reform process is regarded as a complex social phenomenon and like all top-down educational change has a history of being robustly resisted at the school site. A cross-national comparative study, between Ireland and Norway, was chosen as it was capable of giving a broader perspective to the study. Norway was chosen as it was one of the Scandinavian countries – renowned by their social equity and made popular by PISA. The research was continually guided by the comparative education field, including the research of Cook, Hite and Epstein (2004), Arnove (2001), King (2000), Crossley (2000) and Broadfoot (2000).¹⁻⁵

The overarching theme of the study was its exploration of *curriculum as a cross-national and institutional text*. Sub-themes included *pedagogy and assessment*, *organisational supports and structures* and *teaching as a professional praxis*. In the early years of this century all three sub-themes were inter-related on the basis of the pedagogical paradigm shift, in science and mathematics education, to teaching for learning taking individual need into account and promoting self-directed learning and critical thinking. The study considered official policy documents – *policy as text* - and the organisational reforms and perspectives of management and teachers – *policy as professional praxis*. These were explored using *organisational* and *process* dimensions. This theoretical framework was constructed from a number of models in the literature included those of Pinar et al (2002), Lingard et al (2001), Hargreaves and Goodson (1996), Snyder, Bolin and Zumwalt (1992), Bowe, Ball and Gold (1992), Rosenholtz (1991) and O’Buachalla (1988).⁶⁻¹²

The research paradigm most suited to this study was the interpretive paradigm but this was supplemented by a small yet significant quantitative study. A mixed methods approach was taken, in line with the thinking of Tashakkori and Teddlie (1998, 2003).^{13,14} This involved a triangulation of methods: a policy archival study over a forty five year timeframe, from 1960 to 2005, an

exploratory case study in ten schools, five in each country at one snap-shot in time in 2003-2004, and a reflexive and reflective study by the author. Over nine validity tests were used, by Smith (1996) and Yin (2003), to assure the reliability and validity of data collection and data analysis.^{15,16} Great care was taken throughout the study to use ethical procedures, to ensure that all respondents gave their *informed consent* and knew of their right to withdraw at any time. Additional care and sensitivity was required due to the cross-national comparative nature of the study.

There were three major findings from the study. Firstly, the study shows that while *organisational structures and supports* appear necessary, they are not sufficient on their own to empower schools to implement pedagogical reforms for learning in upper secondary science and mathematics education. Secondly, the study shows that the majority of management and teachers in these case study schools, in both Ireland and Norway, were of a traditional mind-set. From the collective evidence it is clear that, in the early years of policy implementation there is a *phase of contestation* by management and teachers. This phase needs to be perceived by policymakers as a prelude to ownership of the reforms rather than an undesirable aberration. Thirdly, the study shows that policy directives in science education in Ireland, such as increasing experimental work, using datalogging and the prospect of a second assessment component, have been tried and tested in Norway and have not succeeded in improving uptake in the physical sciences or mathematics.

The study supported the theoretical generalization of existing models of *the policy process*, by Bowe, Ball and Gold (1992) and the *mutual adaptation model* of Snyder, Bolin and Zumwalt (1992).^{17,18} The study was limited in that it did not include the voice of other key actors, such as policymakers, students or parents. The exploratory nature of the case study meant that, for the most part, it was limited to raising issues requiring further research. A number of recommendations were made including the need in Ireland for a science and mathematics policy into the future and the general need for broader, more horizontal models of inservice education, in Ireland, Norway and elsewhere, connecting management and teachers into a national grid of political, professional and intellectual support more appropriate for the continuing education and professional learning of a teaching force in a knowledge society.

Acronyms

Chapter One

DES	Department of Education and Science
MER	Ministry of Education and Research
MST	Mathematics, Science and Technology
IEA	International Education Achievement
TIMSS	Third International Mathematics and Science Study
PISA	Programme for International Student Achievement
OECD	Organisation for Economic Cooperation and Development
SAS	Science and Scientists
ROSE	Relevance of Science Education
USA	United States of America
USSR	Union of Soviet Socialist Republics
BERA	British Education Research Association
Dáil Éireann	Parliament in the Republic of Ireland
Storting	Parliament in the Kingdom of Norway

Chapter Two

UNESCO	United Nations Educational, Scientific and Cultural Organisation
STS	Science, Technology and Society
ICT	Information Communications Technology
RME	Real Mathematics Education

Chapter Three

QUANT	quantitative
QUAL	qualitative
NCCA	National Council for Curriculum and Assessment

Chapter Four

BOM	Board of Management
TY	Transition Year
TYO	Transition Year Option
LC	Leaving Certificate
LC(est)	Leaving Certificate (established)
LCVP	Leaving Certificate Vocational Programme
LCA	Leaving Certificate Applied
WSE	Whole School Evaluation
SDPI	School Development Planning Initiative
DSE	Discover Science and Engineering
NBSS	National Biology Support Service
ASTI	Association for Secondary Teachers of Ireland
TUI	Teachers Union of Ireland
SEC	State Examinations Commission
ISTA	Irish Science Teachers Association
IMTA	Irish Mathematics Teachers Association
LAOS	Looking At Our Schools
SLSS	Second Level Support Service
PSI	Physical Sciences Initiative
INSET	Inservice Education and Training
CPD	Continuing Professional Development
ICDU	In-Career Development Unit
TES	Teacher Education Service
RDO	Regional Development Officer

Chapter Five

OECD	Organisation for Economic Cooperation and Development
MER	Ministry of Education and Research
MBO	Management by Objectives

R-74	Upper Secondary School Reform 1974
R-94	Upper Secondary School Reform 1994
HoD	Head of Department
FY	Physics
KJ	Chemistry
BI	Biology
MX, MY, MZ	Mathematics
NORDINA	Nordic Studies in Science Education
TIMSS	Third International Mathematics and Science Study
PISA	Programme for International Student Assessment
MST	Mathematics, Science and Technology
VOX	Norwegian Institute for Adult Education
RENATE	National Centre for Contact with Working Life for the Promotion of the Natural Sciences and Technology
ROSE	Relevance of Science Education
OB	Open-Book Assessment project
SITES	Second Information Technology in Education Study
NOK	Norwegian Kroner
SKOLEPAKKE	School Package Agreement
NOMAD	Nordic Studies in Mathematics Education

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Chapter One: Introduction

The phenomenon of interest in this thesis is the effectiveness of translating policy from the rhetoric of state mandated reform to the reality of school-based praxis. It is widely agreed in the literature that effecting deep change in the school system poses real challenges. It is also recognised that change is not going to be effectively implemented if it does not have the overt or at least tacit agreement of management and a sense of ownership by teachers. The substantive issue at the heart of this thesis is identifying the key changes in science and mathematics mandated by the state, in upper secondary academic education, and seeing the extent to which these are translated into school praxis, through the perspectives of management and teachers and, of equal importance, through the organisational and structural reforms taking place at the level of the school. A cross-national comparative study, between Ireland and Norway, was chosen to give a broader perspective. The study was designed mainly as an exploratory qualitative study making use of a small yet significant quantitative dimension. The value of an exploratory research approach is the possibility it presents to identify gaps at the rhetoric-reality interface, make recommendations and seek out areas for future research. It also gives the possibility of theoretical generalisation of the policy process, through the use of qualitative techniques, whereby evidence is provided to formulate a theoretical position that is either similar or different to the existing literature base.

Chapter One presents some background information about the range of international studies in science and mathematics that were influencing policy decisions in the early years of this century. Developed countries were coping with the problem of declining interest in science and mathematics among upper secondary students at a time when economies were increasingly dependent on technological innovation and highly skilled graduates. While there were a range of large-scale international surveys done few

comparative studies focused specifically on the problem. While there were a few studies of this nature in the literature none of them focused exclusively on Ireland and Norway. This gap in the literature provided an additional impetus for the study. The thesis is presented as a tapestry of the policy process in science and mathematics education in one academic programme in upper secondary education in Ireland and Norway. The waft of the tapestry is premised on the inextricable link between curriculum reform and teacher reform, as argued by Dalin (1993).¹ This waft is interweaved throughout by the conceptual framework of O’Buachalla (1988) which places process and organizational issues at the heart of the policy process.² While in the latter quarter of the twentieth century and early years of this century there was an exponential increase in the number of students in post-16 education this was not accompanied by a similar increase in participation levels in the physical sciences and mathematics. Concern at the low uptake of students in the physical sciences and mathematics was an issue in both countries.

1.1 Background and Context for this Study

By the early years of the twenty first century school science and mathematics had positioned themselves at the epicentre of government policy mainly because of the perceived connection between education and economic competitiveness across western European countries, including Ireland and Norway.³ By 2003-2004 Ireland had taken a lead in Europe for the number of tertiary graduates in the 20-29 year old age bracket for *Mathematics, Science and Technology* (MST) per thousand of population.^{4,5} It had attracted high technology foreign industries because of generous corporation tax incentives and the availability of highly educated young skilled graduates of science and technology.⁶ Was it going to be able to retain this competitive edge in the face of a range of factors including the declining uptake in the sciences and mathematics in upper secondary education?

At the time *International Education Achievement* (IEA) studies such as TIMSS 1995 (*Third International Mathematics and Science Study*) and PISA 2000, 2003 (*Programme for International Student Assessment*) focused on scientific and mathematical literacy levels among 15 year olds.^{7,8} Concurrently selecting, attracting and developing quality teachers began to occupy the minds of policymakers and OECD studies (*Organisation for Economic Cooperation and Development*) such as *Teachers Matter* (2005) suggested that teachers involved in reforms needed to have a sense of ownership and not just behave as passive functionaries in the policy process:

Experience from a number of countries indicates that unless teachers and their representatives are actively involved in policy formulation, and feel a sense of “ownership” of reform, it is unlikely that substantial changes will be successfully implemented.⁹

Large scale international policy-borrowing increased among OECD countries and other countries studied the model of education in Finland to decipher the conditions that gave it a lead role at the top of these literacy league-tables.¹⁰ Finland, similar to its’ Nordic neighbours, made a substantial investment in its public schooling matched with similar investment in the quality of their teaching force. Simola’s (2005) research indicated that teachers in Finland enjoyed high status, were authoritarian within a collective culture and pedagogically conservative.¹¹ She argued that comparative studies should encompass a historical dimension.¹² Cherry-picking findings to weave a common yardstick of global benchmarking, using a type of cognitive Olympics, might prove far more complex than at first anticipated. Tamir (2004) warned of the complexity of the reform process:

If many of the expectations have not been fully fulfilled, the reasons lie in part in the naivete of the enthusiasts of the 1960’s, who failed to comprehend the complexity and the difficulty of the task they had undertaken; and in part the failure to fully conceptualise the critical role of implementation, namely dissemination, teacher education and monitoring, and supporting utilization at the classroom level.¹³

In PISA 2003 Ireland achieved a mean score of 505.4 for scientific literacy, ranking 16th of forty countries.¹⁴ Low achievers were performing relatively well in science while high achievers were not performing to their potential. The studies indicated similar findings for mathematics.¹⁵ Mid-range test scores were also found for Norway in PISA 2000 while in PISA 2003 it was ranked at number 17 in mathematics and number 13 in the natural sciences.^{16,17} Norwegian researchers became concerned that knowledge of science and mathematics had declined between 1995 and 2003:

The truth that these two sets of data, to a large degree, both confirm and supplement each other, and thus give a consistent picture of a problematic situation for mathematics and science in our country. Some bells are ringing, and we hope they are being heard!¹⁸

These IEA studies were supplemented by other large scale cross-national studies such as SAS (*Science and Scientists*) and ROSE (*Relevance of Science Education*), enquiring into pupils attitudes toward science.¹⁹⁻²⁰ All studies indicated that science and mathematics had a deeply-rooted image problem among young people in developed countries. The compelling results from these international studies and the decline in uptake in the physical sciences and mathematics brought this issue on to the agenda of government cabinet tables and took on strategic importance for the Ministries of Education. In Ireland the then Minister for Education and Science, Michael Woods, T.D., set up a forty-four person *Task Force on the Physical Sciences* in October 2000 to research the issue and a final report was published in March 2002.^{21,22} The need to stimulate the uptake of the sciences moved onto the national policy agenda and remained there for the duration of this research study, as indicated in this statement by the Minister for Education and Science, Mary Hanafin T.D., reporting to Parliament (*Dáil Eireann*) in 2004:

The numbers taking science have serious implications, not alone with regard to educational value but also for the economy, particularly with regard to inward investment of major medical and pharmaceutical companies.²³

In 2002 the Minister for Education in Norway, Kristin Clemet, initiated a national strategy to cohere a number of national organizations to improve the status of science and mathematics in society and in schools.²⁴ A new comprehensive reform policy *Mathematics, Science and Technology* (2005) was formulated as a national strategy, *Realfag Naturligvis* (natural sciences, naturally), for strengthening science and mathematics from kindergarten through to upper secondary education.²⁵ Comparisons may be drawn between this frenzy for new policies in science and mathematics and the threat felt by Europe and the USA when the USSR launched the space shuttle Sputnik in 1957.²⁶ Fear of being left behind in the space race and the implications for their science and technological development spurred all western and European countries to engage in national reforms of their school science and mathematics programmes. These older academic subjects were presented as abstract theoretical subjects with little consideration for the conceptual development or motivation of students. The approach taken at the time ultimately failed to attract students in any significant numbers. Was there a danger of history repeating itself?

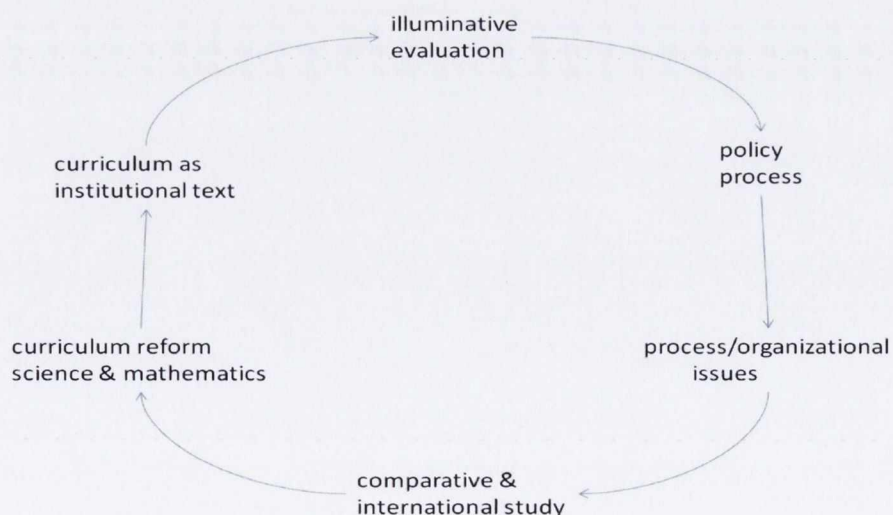
Between 1995 and 2005 an international and comparative research literature review showed that the policy discourse on science and mathematics was mostly confined to large scale cross-national surveys. For example, few research studies in the *Comparative Education Review* and *Comparative Education* were concerned with subject matter change (Mullens, Murnane and Willett (1996); Wolf and Steedman (1998); Jordan and Yeomans (2003); McEneaney (2003)).²⁷⁻³⁰ Only one of these studies was concerned with high school students. Similarly few comparative studies were concerned with the changing comparative conception of teaching (Pritchard (1983); Judge (1988); Stephens, Tønnessen and Kyriacou (2004)).³¹⁻³³ No study inquired specifically into high school science and mathematics reforms in Ireland and Norway. This thesis aims to fill this research lacuna.

What precisely were the pedagogical reforms, structural reforms and teacher reforms in science and mathematics upper secondary education? Would using a historical lens, from 1960 to 2005, help illuminate these reforms and identify significant patterns? To what extent was adaptation of the rhetoric reflected in the perspectives of school management and teachers? Such key questions were scaffolded by a theoretical framework and from this research questions were decided. It is to these matters that we now turn.

1.2 Theoretical Framework for the Study

The flow-chart underpinning initial thinking about the theoretical framework shows progression from an illuminative evaluation of a comparative and international study delving into curriculum reform through consideration of a range of process and organizational issues (Figure 1.1). This assists in visualising the various aspects of the study that need to be considered in the literature review including: the complexity of the change process, the policy process, and a comparative study of curriculum reform as subject matter change, teacher reform and organisational reform.

Figure 1.1 Flow-chart underpinning the initial thinking phase for this research study.



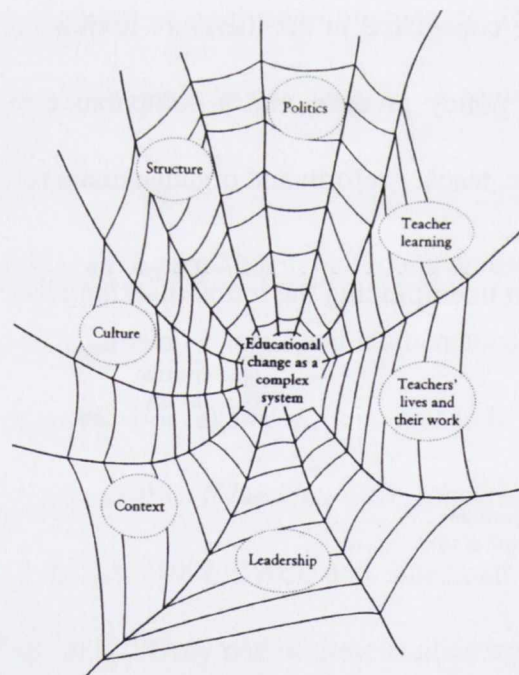
Source: Author.

The complexity of the educational change process was highlighted by both Fullan (2000) and Hoban (2002).^{34,35} Fullan (2000) documented the history of reform failure, the social complexity of change and the need for shared ownership and meaning among all actors in the process. He highlighted the need for clarity in the policy process:

Clarity (about goals and means) is a perennial problem in the change process. Even when there is agreement that some kind of change is needed, as when teachers want to improve some area of the curriculum or improve the school as a whole, the adopted change may not be at all clear about what teachers should do differently.³⁶

Hoban (2002) used a web model to highlight the complexity of educational change (Figure 1.2).³⁷ This showed the entangled mesh of the change sub-systems including structures, teaching and learning and teachers' lives and their work within a socio-cultural context.

Figure 1.2 Hoban's (2002) web-model indicating the complexity of educational change.



Source: Hoban, Garry F. (2002) *Teacher learning for educational change A systems thinking approach*, Buckingham and Philadelphia: Open University Press, 37.

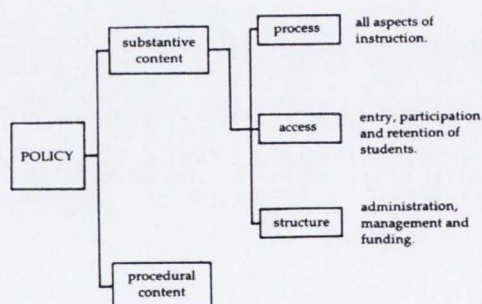
The policy process, as the phenomenon under study, needed to be opened out for a critical appraisal. Hamilton (1976) argued for a type of illuminative evaluation which he stressed was more holistic and illuminative than evaluative in the classical sense:

Illuminative evaluation (as this is the term that occurs most frequently) seeks to open out an educational situation to intelligent criticism and appraisal.³⁸

Bowe, Ball and Gold (1992) used a sociological lens and triangulated the policy process within three different contexts: *policy as influence*, *policy as text* and *policy as practice*.³⁹

Policy as influence considered the key stakeholders, *policy as text* referred to the official documentation that emerged while *policy as practice* represented policy as implemented in schools. It is the latter two aspects of this model, *policy as text* and *policy as practice* that this thesis considers. O’Buachalla (1988), whose seminal text *Education Policy in Twentieth Century Ireland* explores the interaction of the main organizations and actors shaping the education system, concluded that the substantive issue at the heart of education policy may be summarized through consideration of three dimensions: process, access and structure (Figure 1.3).⁴⁰

Figure 1.3 O’Buachalla’s (1988) schema for the dimensions of the policy process.



Source: Ó’Buachalla, Séamas. (1988) *Education Policy in Twentieth Century Ireland*, Dublin: Wolfhound Press, 328.

These dimensions were adapted for this study and presented as process and organisational dimensions. A fuller explanation is given in Chapter Two. Historically the field of comparative and international research arose from a blend of the more academically oriented arena of theoretically informed comparative education and the more applied practitioner oriented international education.⁴¹ The field moved from largely quantitative studies in the 1960s to embrace a considerable range of epistemological and theoretical diversity in the early years of this century. Crossley and Watson (2003) called for a reconceptualisation of the field that was sensitive to cultural context while arguing for the need for historical insights for future policy action.⁴² Cross-national comparative studies, according to Kohn (1989), sought to identify similarities and differences between phenomena while gaining a better understanding of one's own system.⁴³

A number of comparative researchers highlighted the complexity of doing comparative research across national boundaries including: King (2000); Crossley (2000); Broadfoot (2000); Arnove (2001) and Cook, Hite and Epstein (2004)).⁴⁴⁻⁴⁸ Rust et al (1999) argued that the comparative researcher is forced to hold the tension of being both a scientist and social scientist simultaneously.⁴⁹ A comparative study offered the possibility of a broader perspective, facilitated theory making and showed similarities and differences between countries as they grappled with similar problems. Ireland was considered as the major domain of the study and Norway as the minor domain. The focus within this comparative study is on reforms within the science and mathematics segment of the formal academic high school curriculum.

Curriculum reform had been reconceptualised as a field of study from the 1980s onwards. According to Pinar et al (2001) divergent discourses ranged from curriculum as political text, curriculum as historical text, curriculum as biographical text to discourses relevant to this thesis: curriculum as *comparative and institutional text*.⁵⁰ This formed the overarching

theme of the study. Curriculum reform defined top-down state-mandated changes in the content and organization of what is to be taught.⁵¹ The study focused on the academic segment of the formal high school curriculum that is concerned with science and mathematics. Goodlad (1984) categorized goals for schooling as academic, vocational, civic, social and personal and noted that academic goals were perceived by pupils, teachers and parents to be the major goals at all levels of schooling.⁵² The academic part of the high school curriculum has traditionally been the access route to university and higher education:

The evolution of school subjects is an understudied aspect of curriculum. From a superficial perspective school subjects may be perceived to be stable, immutable, enduring.⁵³

While policymakers had remained largely silent on pedagogical reform in the twentieth century this changed from the nineteen nineties and early years of this century. The western world post-PISA became focused on the need for students to develop higher order thinking skills and become critical thinkers and self-directed learners. The knowledge economy demanded it. Public school teachers were being asked to become facilitators of learning, capable of teaching a diversity of students and giving individual student feedback. This thinking was supported by the productive pedagogies model of Lingard et al (2003).⁵⁴ It was accompanied by the conception of assessment for learning by Black and Williams (1998).^{54,55}

Snyder, Bolin and Zumwalt (1992) presented a model of curriculum implementation based on three different designs.⁵⁶ The design most suited to this thesis was the *mutual adaptation model* which acknowledged that official guidelines undergo a process of adaptation inside the school. Studies in the late nineteen eighties and early nineteen nineties, Goodlad (1984) and Rosenholtz (1991) showed that teachers worked best in learning-enriched conditions.^{57,58} Rosenholtz (1991) developed criteria for classifying

schools based on the degree to which they proactively promoted teacher learning..⁵⁹ These criteria were adapted for this study (see Chapter Two). Although teaching *as a professional praxis* was contested there was a growing international research movement progressing this thinking: Hargreaves and Goodson (1996); Fullan (2000); Hoban (2002) and Darling-Hammond and Bransford (2005).⁶⁰⁻⁶³ Despite this growing movement to build teacher autonomy there was also, during the early years of this century, a counter movement to deprofessionalise teaching with monitoring, accountability and increased national testing at the level of the state.

In conclusion, the change process was perceived as complex and multivariate. Fullan's (2000) conception of clarity of goals was required.⁶⁴ The *mutual adaptation model* of curriculum implementation proposed by Snyder, Bolin and Zumwalt (1992) was used, O'Buachalla's (1988) dimensions of process, access and structure were adapted for the study, the complexity of teaching was viewed through Rosenholtz's (1991) framework for teacher learning while overall the policy process was considered through the lens of Bowe, Ball and Gold's (1992) amended model of *policy as text* and *policy as professional praxis*.⁶⁵⁻⁶⁸ Finally a selection from this literature was made that fitted with the main research focus for the study. The conceptual models chosen had a number of overlapping aspects and these were studied and further refined. The outcome was the development of a novel theoretical framework for the data analysis at both the macro- and micro levels. The overarching theme for the study was *curriculum reform as institutional and cross-national text*. The main focus was on developing *teaching for learning* underpinned by three sub-themes: *pedagogy and assessment in science and mathematics*, *organisational changes to support science and mathematics reforms* and *teaching as a professional praxis* (Figure 1.4). These sub-themes were conceptualised from the study of relevant literature and stated as follows:

- **Pedagogy and Assessment:** This sub-theme considers the pedagogical practices recommended in the reforms in science and mathematics upper secondary academic education. It is related to teachers' everyday work and inextricably links teaching, learning and assessment for the development of a culture of learning.
- **Organisational Structures and Supports:** This sub-theme suggests that the new learning paradigm, recommended in the science and mathematics reforms, requires different organisational structures and supports at the level of the school – facilities, resources, teacher-teacher meetings times – than was required for previous reforms that supported more teacher-centred forms of schooling.
- **Teaching as a Professional Praxis:** This sub-theme regards the teacher as a professional learner, within a post-modern conception of the teacher as professional, and recognises the need for teacher collaboration, pre-preparation for teaching for individual need, teacher evaluation, both self-evaluation and peer evaluation, and opportunities for teacher continuing learning and education.

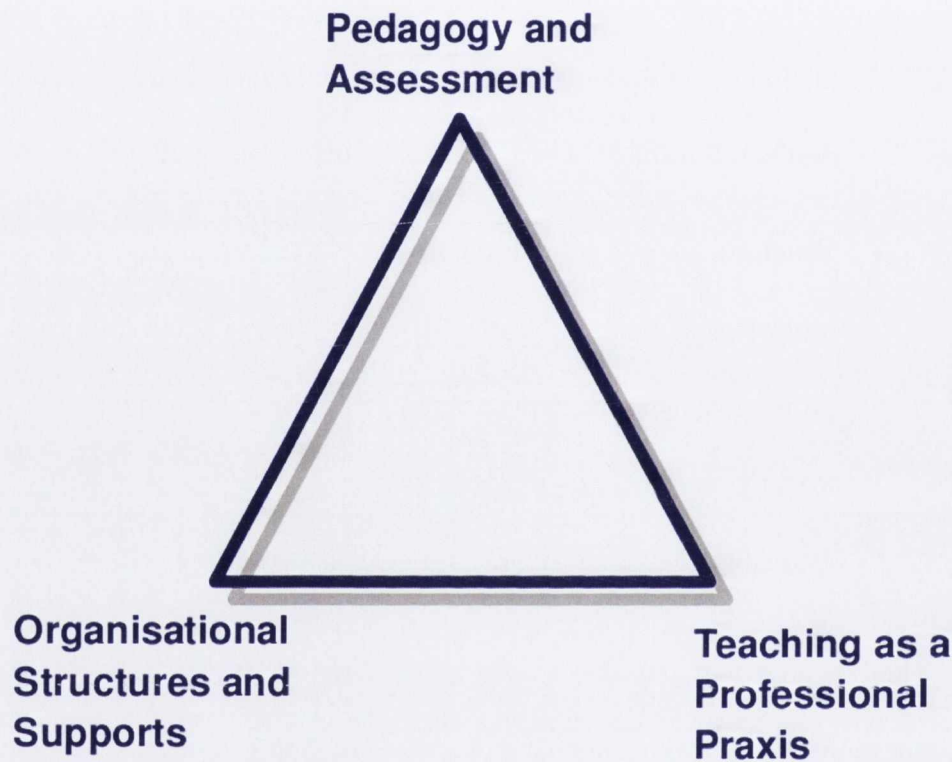
This ensured a theory-driven study was used to support the formulation of research questions while setting boundaries for the sampling and selection decisions. This aspect of the study is now considered.

1.3 Research Questions

The research study explores that aspect of the policy process that is concerned with science and mathematics in upper secondary academic education. The phenomenon under study seeks to track key reforms as they flow from the state-house to the school-house. The focus of the study was the interface between the official policy documents coming from the state to the school and the perception of the management and teachers to the

reforms coupled with the structural implications of the reforms. The study seeks to ascertain similarities and differences between the two countries and the level of congruency found between the rhetoric of *policy as text* and the reality of *policy as professional praxis* as perceived at the management-teacher interface within the school context.

Figure 1.4 The three sub-themes underpinning the thesis.



Source: Author.

Generating key questions was an iterative process that was revisited regularly and was not a simple linear process:

Formulating the questions is an iterative process, the second version is sharper and leaner than the first, and the third gets the final few bugs out.⁶⁹

The study considers five research questions, across each country, at both macro- and micro-levels in science and mathematics upper secondary academic education:

1. What is the overall shape of the policy process nationally and school-based?

2. What were the main curricular changes and how were these supported by changes in pedagogy and assessment?
3. What organizational changes were supporting these reforms?
4. What was the changing role of the teacher with regard to the reforms and in what ways were teachers given opportunities for continuing professional learning?
5. What types of graduation patterns were found and how many schools and teachers were in each education system?

Once the key questions were identified the research design and research plan was used to decide on the most appropriate methodology and the ethics, reliability and validity of findings. It is to these matters that we now turn.

1.4 Research Rationale, Design, Methodology, Ethics, Validity and Reliability

The research questions set the stage for the research rationale and research plan. The research rationale was considered from the perspective of the research paradigm used and the epistemological and ontological assumptions of the researcher. While the research design involved dividing the study into two sections, *policy as text* and *policy as professional praxis*, the research plan involved selection of the appropriate research methodology. It also considered all aspects of ethics and quality control and the great care needed to ensure reliability and validity of the findings. While this section gives an overview of the research rationale details of the full research literature review, and the approach taken to all aspects of this research, may be found in Chapter Three.

1.4.1 Research Rationale

While the latter half of the twentieth century was marked by distinct wars between the positivist-naturalist divide the early years of this century are marked by a higher level of tolerance and respect for diversity of research methods. In addition to the three research paradigms, positivistic, naturalistic and critical theorist, a fourth one has taken shape since the beginning of the new millennium. This is termed mixed methods research where, as argued by Tashakkori and Teddlie (1998, 2003), knowledge is positioned along a continuum between totally objective at one end to totally subjective at the opposite end of the spectrum.^{70,71} While the positivist or the naturalist may reside at either end of this continuum there is ample space toward the middle where knowledge may be found in an intermediary position.

Rust et al (1999) in an extensive literature search of peer-reviewed articles in three well known journals, in the comparative and international field of study, noted that most comparative studies did not detail their data collection or data analysis methods.⁷² They noted the congruency between philosophical underpinnings and researchers positions with respect to the epistemology of knowledge production and their ontological values:

Ontologically speaking, quantitative researchers tend to argue that reality is objective and singular, existing apart from the researcher, while qualitative researchers tend to see reality as being subjective and multiple. Epistemologically speaking, quantitative researchers tend to claim that they are outside their sphere of research, while qualitative researchers tend to believe that they are continually interacting with the subject matter being researched.⁷³

The comparative research field was mostly shaped by qualitative studies although these were often supplemented by descriptive quantitative statistics:

comparative educators would tend to see reality as somewhat subjective and multiple, rather than objective and singular. Epistemologically, comparative educators would tend to interact with that being researched rather than acting independently and in a detached manner from the content....Even with such an overwhelming tendency toward qualitative research, it is also clear that quantitative studies play a minor though important role in the field.⁷⁴

1.4.2 Research Design

This study inquired into the policy process through two distinct phases: coarse grain knowledge about the policy process in each country over an extended timeframe and fine-grain knowledge about schools in one snap-shot in time in the early years of this century. The coarse grain knowledge was obtained through an analysis of the official policy documents, in both countries, from 1960 to 2005. The fine-grain knowledge was found through an exploratory case study of ten schools, five in each country in 2003-2004. Comparative education draws from a range of research methodologies to answer critical questions posed:

Comparative educators are free to draw on those methods of inquiry that seem most appropriate to them to answer the research questions that have been posed.⁷⁵

1.4.3 Research Methodology

The macro research study involved an archive study of official policy documents, such as government publications and parliamentary reports in Ireland (*Dáil Eireann*) and Norway (*the Storting*). The comparative nature of the official document search was facilitated by access to documents in both Ministries of Education through the internet.⁷⁶ This comparative case study research followed the guidance of Crossley and Vulliamy (1984) and Stake (1994, 1995).⁷⁷⁻⁷⁸ This took a number of factors into account including the potential of exploratory studies, of a cross-national comparative case nature, to generate insights and extend existing theory. Data collection methods included interview transcripts, field notes from observations, official documents, questionnaires and official statistics. Data analysis involved working with the data, organizing it and breaking it down into manageable units and ultimately synthesizing and searching for patterns. While there are guidelines for data analysis there are no universal agreed canons and the researcher has

to use their intellect to communicate what the data reveals. The field notes were written up immediately after each visit to the school:

After returning from each observation, interview or other research session, the researcher typically writes out, what happened. He or she renders a description of people, objects, places, events, activities, and conversations. In addition, as part of such notes, the researcher will record ideas, strategies, reflections, and hunches, as well as note patterns that emerge. These are fieldnotes: the written account of what the researcher hears, sees, experiences, and thinks in the course of collecting and reflecting on the data in a qualitative study.⁷⁹

Making sense of large amounts of data involves an interaction with the data that renders it transformed. Patton (2002) refers to the process as a catalytic conversion:

The inquirer acts as catalyst on raw data, generating an interaction that synthesises new substance born alive from the catalytic conversion.⁸⁰

Qualitative inquiry methods provide opportunities to achieve empathy, a type of *empathic neutrality*, giving an empirical basis for describing the perspective of others.⁸¹ The words and phrases, in this research study, were divided into coding categories that were related to the themes driving the study. The evidence emerging was reflected and refracted through O’Buachalla’s (1988) adapted dimensions of process and organization.⁸² Even when research begins within a theoretical framework, a deductive approach, the researcher finally strives to look inductively at the data for emerging undiscovered patterns and understandings:

Qualitative analysis is first deductive or quasi-deductive and then inductive (it begins by examining the data in terms ofapplying a theoretical framework... after or alongside this deductive phase of analysis, the researcher strives to look at the data afresh for undiscovered patterns and emergent understandings (inductive analysis).⁸³

1.4.4 Research Ethics

Research studies need to be conducted in ways that are ethically sound and cause no harm to respondents. This involves being aware of the moral and legal dimensions of the codes of ethics for researchers. For example, the *British Education Research Association*

(BERA) publishes ethical guidelines for researchers advising how to conduct educational research in ways that are not potentially harmful to respondents.⁸⁴ It was necessary to ensure that all participants in the study were fully aware what the research was about, had an opportunity as respondents to be fully informed, to be involved voluntarily and to know of their right to withdraw from the study at any stage. Robinson-Pant (2005) highlights a number of distinctive ethical issues facing cross-national comparative researchers.⁸⁵ This required additional sensitivity and sensibility as the researcher was *an insider* in one country and an *outsider* in the other country. Individuals and cultures do not share the same sensitivities and researchers need to be aware of this lest superficial readings are drawn from the findings.

1.4.5 Validity and Reliability of Data Collection and Data Analysis Methods

Quality assurance indicators for social science research include reliability and validity of data and findings. Multiple sources of data, multiple methods and multiple perspectives were all used, in this study, to enhance the validity and reliability of the data collected and increase its trustworthiness. Great care was taken to ensure that the findings have validity - that the research tools were measuring and describing what they were supposed to measure and describe. The validity of the research instruments was strengthened by the fact that the areas of focus emerged from the theoretical framework rather than being imposed by the researcher. Making a claim to knowledge requires that data collection methods and data analysis approaches are all conducted following a number of research protocols and subjected to a range of tests and criteria so that reliability and validity of findings may be assured. In this study the five criteria for validating qualitative research by Smith (1996) - *internal coherence, presentation of evidence, independent audit, triangulation and member validation* - and the four tests advocated by Yin (2003) - *construct validity, internal validity, external validity and reliability* - were used to guide this aspect of the

study and give quality assurance.^{86, 87} In addition to these tests this researcher, neither believing in unbridled subjectivity nor absolute relativism, sought to reduce researcher bias through a reflexive and reflective process. These tests and approaches included using a range of lenses to triangulate multiple perspectives, having a theoretical framework, using multiple sources of evidence, cross-checking data, having key informants review drafts of the case report, pattern-building and searching for rival explanations. These are all dealt with in greater detail in Chapter 3, Section 3.6.

1.5 Limitations of the Research Study

This cross-national comparative study was designed to gather data from two distinct sources: the official policy documents related to science and mathematics and the case study school findings, five in each country. While the official policy text analysis was extensive and conducted over a forty five year time-frame the case study school research was confined to one snap-shot in time, 2003-2004. The case study was limited in that it only identified the organizational reforms made, to support the state-mandated changes recommended, and the perspectives of key policy-gatekeepers, management and teachers. This micro-level study did not seek the perspectives of other significant actors such as students or parents. While it sought information about the formal structures for teacher meetings it did not enquire into the quality of these interactions. The macro study did not explore *policy as influence* and seek the national policymakers' perspectives. These limitations also point the way forward for future cross-national research studies.

1.6 Layout of the Thesis

Chapter One presents an overview of the entire thesis. It begins with consideration of the current wave of large scale international studies and how these have led to policy-borrowing between nations. The theoretical framework for the study is introduced and key

questions driving the research are identified. Some research considerations, such as research design, rationale, ethics, methodological decision-making are taken into account. The ontological and epistemological values of the researcher are briefly considered as are the steps taken to ensure reliability and validity of findings.

Chapter Two presents the full international literature review that supports the thesis. This shows how the study was first and foremost a cross-national comparative study and shows the development of the theoretical framework. It gives the overarching theme for the study and the key theorists that influenced the study. Finally the sub-themes of the study are developed from an exchange with the relevant literature.

Chapter Three presents the research review for the study and deals in detail with the way this research study was formulated, designed, planned and executed. The chapter deals with the full range of research considerations including: research rationale, design, methodology, ethics, reliability, validity and limitations of the study. The research design is presented and key research canons and principles that influenced the planning, the selected methodologies and the triangulation approach are considered. This chapter charts the great care taken to ensure that ethical issues received their full attention and the tests used to assure the reliability and validity of data collection and data analysis.

Chapter Four deals with the policy process in upper secondary science and mathematics education between 1960 and 2005 in Ireland. The study using a historical and interpretive lens charts the main curricular waves during the time-frame. The findings show lack of clarity between official documents and methods of assessment. They also show a lacuna in the policy process with respect to science and mathematics and teacher continuing education Chapter Five deals with the policy process in upper secondary science and mathematics education between 1960 and 2005 in Norway. Findings indicate the high

level of investment in high school education and the emphasis on policy planning. The national curriculum guidelines emphasise *adapted teaching* to suit the needs of each learner. Findings in this part of the study show the challenge inherent in the espoused policies and the oftentimes inertia of an ageing teaching force.

Chapter Six and Chapter Seven consider the case study findings from each country. These chapters present the organizational changes being implemented in the schools in 2003-2004. The perspectives of the management and teachers give an indication of the extent to which they perceive the reforms to be either minor technical changes or major cultural reforms. From consideration of the process and organisational dimensions a landscape emerges of varying organisational investment while management and teachers perspectives, at that point in time, present a common thread of contestation and traditional thinking. The similarity between both countries in this regard presents compelling evidence for the complexity of the social phenomenon that is the policy process and the challenge this presents to reconceptualise teacher ongoing professional learning.

In Chapter Eight the various aspects of the study are threaded together and subjected to a comparative analysis based on the theoretical frame for the study. Research questions are revisited. Similarities and differences between systems emerge and gaps are identified. The findings assist the theoretical generalisation of two existing models: Bowe, Ball and Gold's (1992) sociological model for *the policy process* and Snyder, Bolin and Zumwalt's (1992) *mutual adaptation model* of the curriculum implementation.^{88,89} The implications of the study for *professional praxis* and for policymakers are discussed and some *blue-skies thinking* and recommendations are suggested.

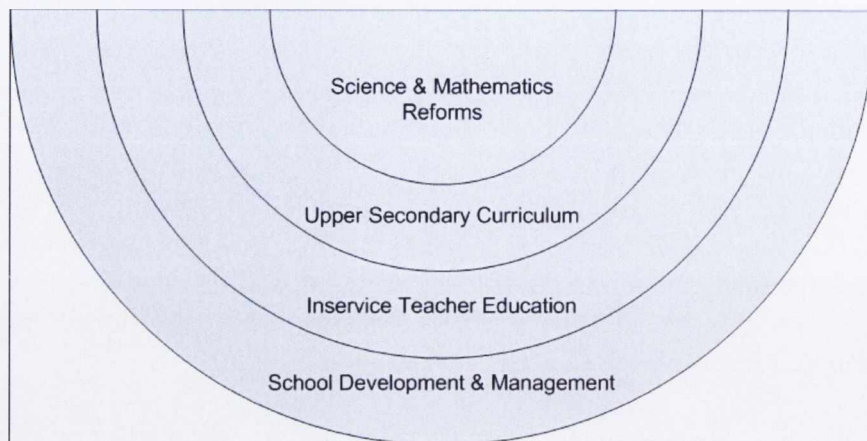
Chapter Two: International Literature Review

This research study is first and foremost a cross-national comparative study in high school science and mathematics education between Ireland and Norway. The focus of the study is on pedagogical, structural and teacher reform in science and mathematics in upper secondary academic education. The main theoretical conceptions underpinning the various aspects of this study, the complexity of the change process, the policy process and a cross-national comparative study of curriculum reform, as pedagogical reform, structural reform and teacher reform, are each considered in turn in this chapter. This study aims to add to the epistemological base with regard to the policy process of science and mathematics reforms and to highlight challenges that remain to be overcome. However while the study specifically focuses on science and mathematics reforms, it is expected that the research findings will have wider application and will extend the conceptual framework with regard to the policy process in general.

The research study was premised on the inextricable link between curriculum reform and teacher reform as identified by Callan (2006), Nieveen (2005), Leech (2005), Dalin and Rolff (1993) and Bowe, Ball and Gold (1992).¹⁻⁵ Science and mathematics reforms do not take place in a vacuum. They are curriculum components of a broader landscape and their implementation is influenced by a number of factors, including the type of teaching offered, the level of planning that occurs and the structures to support new ways of teaching. An image of a water bath, with several subsections, may be used to visualize this aspect of the context of the school-based reform process (Figure 2.1). The school community with pupils, teachers and management continually interact with each other and with a number of external agents. These external agents include parents and guardians and a range of actors from state agencies with responsibility for education. Within this group

of internal and external actors the zone of influence being explored is the teacher-management interface (Figure 2.2).

Figure 2.1 Science and mathematics reforms in upper secondary education.



Source: Author

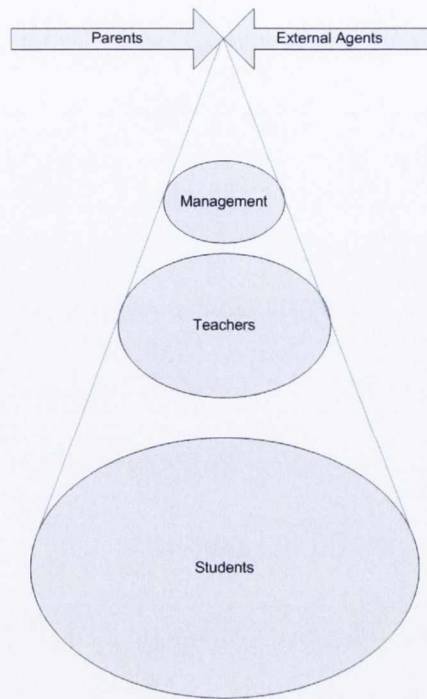
When policy enters the school through circular letters, inservice events, external agents or other measures key internal people need to gain ownership of the changes so that they will be implemented. These key actors include management and teachers. They are significant gate-keepers for reform: with their support some measure of change can take place, without their support reform is doomed to failure.

2.1 Cross-National Comparative and International Study

Cross-national comparative and international studies have interested researchers for many years with comparative education grounded in the theoretical and academic and international studies based on more practitioner-oriented field studies.⁶ The curiosity that underpins the field is the need and desire to learn more about one own's perspective through a critical review of what happens in other countries:

To develop a critical stance on one's own existential world and that of those in distant lands, as the German philosopher Hegel pointed out over 190 years ago in his *Nürnberg Schriften*, one "must make a home in the other." For Hegel, a proper education would be impossible without a fully international course of study. Only by knowing other realms of being, by real and vicarious travel.....can one begin to gain distance on one's own daily existence, what is unique about it and what is shared with others.⁷

Figure 2.2 Zones of influence within a school-based reform process.



Source: Author

Crossley and Watson (2003) call for a reconceptualisation of the field so that it becomes sensitive to cultural context while arguing for the need to gain comparative historical insights for future policy action.⁸ Comparative education traditionally seeks to identify similarities and differences between systems while gaining a better understanding of one's own education system.⁹ A number of comparative researchers highlight the complexity of doing comparative research across national boundaries: King (2000); Crossley (2000); Broadfoot (2000); Arnove (2001) and Cook, Hite and Epstein (2004).¹⁰⁻¹⁴ Rust et al (1999) argue that the comparative researcher is forced to hold the tension of being both a scientist and social scientist simultaneously.¹⁵

Few research studies in the *Comparative Education Review* and *Comparative Education* were concerned with subject matter change: Mullens, Murnane and Willett (1996); Wolf and Steedman (1998); Jordan and Yeomans (2003) and McEneaney (2003).¹⁶⁻¹⁹ Similarly few comparative studies were concerned with the changing comparative conception of

teaching: Pritchard (1983); Judge (1988); Stephens, Tønnessen and Kyriacou (2004).²⁰⁻²²

No study inquired specifically into high school science and mathematics reforms in Ireland and Norway. The value of research in comparative contexts as argued by Stenhouse (1975) is in providing insights rather than generalisable laws.²³ Arnone (2003) argues that a cross-national comparative study forces the researcher to think in a larger context:

Comparativists can make their greatest contribution to improve theory and policy by attempting to introduce as many levels of analysis as possible to portray the complex interplay of different social forces and how individual and local units of analysis are embedded in multiple layered contexts.²⁴

The concept of using comparative research to gain a deeper perspective was also argued by Beauchamp (1998) who, while warning that we cannot borrow from other societies, suggests that a conscious recognition that there are other ways of doing things can serve to open our minds in ways that might not otherwise be considered:

Perhaps equally important, however, is the valuable perspective that studying another education system (or its problems) provides us in understanding our own system (or its problems). When we step beyond our own limited experience and our commonly held assumptions about schools and learning in order to look back at our system in contrast to another, we see it in a very different light.²⁵

2.2 Complexity of Educational Change

Fullan (2000) presented the failure rate of many large-scale reform studies and suggested that change was not an event but a process and noted the critical importance of winning the teacher's heart in the change process.²⁶ He considers the multidimensional and multivariate nature of change and suggests that it often includes the use of new teaching approaches, changes in pedagogical assumptions among teachers and supportive infrastructure. The rhetoric-reality prism used is based on Fullan's (2000) thinking with regard to the need for clarity of goals and means in implementation:

Clarity (about goals and means) is a perennial problem in the change process. Even when there is agreement that some kind of change is needed, as when teachers want to improve some area of the curriculum or improve the school as a whole, the adopted change may not be at all clear about what teachers should do differently.²⁷

In a study in the Czech Republic Polyzoi and Cerná (2001) used Fullan's (2000) conception of educational change to ascertain the extent of change since the Velvet Revolution in 1989.²⁸ Their study recommended an even more dynamic model of educational change based on a transformative model. Hoban (2002) represented the complexity of the educational change process through a web-like model showing the interconnectivity of a range of different competing aspects.²⁹

2.3 Macro Policy Process

The macro policy landscape involves a range of actors including policymakers and key stakeholders in a political and professional process. Rust and Blakemore (1990) consider the extent to which corporatist political theory, theories of the state, explain the types of educational reforms in Norway, England and Wales.³⁰ They found that while the model has shortcomings it helps explain the approaches countries use for educational reform. The macro policy process has been studied using sociological and historical lenses by O'Buachalla (1988), Bowe, Ball and Gold (1992) and Young (1998).³¹⁻³³ O'Buachalla (1988) argued that the substantive issue at the heart of education policy may be summarized through consideration of three dimensions: process, access and structure.³⁴ This schema was adapted and situated within a socio-cultural context: process issues were retained while access and structure dimensions were subsumed into organizational issues (Figure 2.3). The process dimension considers such aspects as pedagogy and assessment while the organisational dimension considers the range of practical scaffolds provided.

Figure 2.3 Adaptation of O’Buachalla’s (1988) policy dimensions.



Source: Author.

Bowe, Ball and Gold (1992) used a sociological lens and presented the policy process as triangulated within three different contexts: *policy as influence*, *policy as text* and *policy as practice*.³⁵ It is the latter two aspects of this triangular model, *policy as text* and *policy as practice*, renamed *policy as professional praxis*, that this thesis considers. Ball (1998) and Young (1998) present curriculum as a selection from culture and argue that each syllabus is dependent on the intellectual climate of the day.^{36, 37}

2.4 Micro Policy Process

While at macro level there are governments, Ministries, a variety of stakeholders and international influences like OECD and *United Nations Educational, Scientific and Cultural Organisation* (UNESCO), at the micro level there are local agencies involved and ultimately the school, school leadership, teachers, parents and pupils.^{38,39} By the early years of this century schools were being mooted as autonomous units of educational change and given higher levels of responsibility with respect to management and

administration. Schools were expected to deliver social change and academic achievement to an increasing diversity of pupils and become communities of learners while being subjected to increased levels of monitoring and public accountability through different models of evaluation. Bowe, Ball and Gold (1992) argue that management and teachers do not approach policy as mere conformists:

Practitioners do not confront policy texts as naïve readers, they come with histories, with experience, with values and purposes of their own, they have vested interests in the meaning of policy. Policies will be interpreted differently as the histories, experiences, values, purposes and interests which make up any arena differ. The simple point is that policy writers cannot control the meanings of their texts.⁴⁰

Researchers of school based reform, Brooke-Smith (2003), Senge (2000) and Hargreaves and Evans (1997), argue for the need to develop a vision and practice that would empower the school community to lead learning.⁴¹⁻⁴³ Similar to *Le Chatelier's Principle* in chemistry which states that during a chemical reaction a system when disturbed seeks to return to equilibrium. When top down school-based curriculum change is responded to the school system adapts in ways that often return it to a stable unchanged equilibrium. Schools as institutions have been remarkably resistant to change and as socio-political-cultural organizations their traditions are organised in ways that resist change even when society and policymakers deem these changes to be worthwhile and necessary.

Hargreaves and Evans (1997) recognize that mere mechanical obedience to reforms does not sow the seeds necessary for the type of intellectual adventure, and the development of a more questioning culture among staff, needed to raise standards and quality in schools.⁴⁴

The collaborative nature of the way teachers' need to work has been identified by Dalin and Rust (1996) when they refer to the need for a *critical mass* to sustain a vision of education.⁴⁵ The essence of change in schools will be their capacity to develop both teachers and students as learners:

Good teachers are also good learners. Better learning among pupils in classrooms comes about when there are strong professional cultures of teaching in staffrooms. So to say that we must include teachers in change and help strengthen the cultures that bind them to their colleagues is not to be romantic or sentimental about teachers; it is to face up to the realities of teaching and how teachers change for the better.⁴⁶

Hargreaves and Hopkins (1991) argue that time for teachers to learn is a key issue and is a balance that needs to be achieved if schools are to embrace change.⁴⁷ Time as an issue is also mentioned by Stoll, Earl and Fink (2003) who argue that protected time needs to be set aside for this type of professional learning by teachers.⁴⁸ This thesis considers the learning environment created inside the case study schools through a range of organizational issues, including the protected time for teachers to meet and evaluate their teaching both individually and collectively.

2.5 Curriculum Reform

Curriculum reform was reconceptualised as a field of study from the 1980s onwards. According to Pinar et al (2002) divergent discourses ranged from curriculum as political text, curriculum as historical text, curriculum as biographical text to discourses relevant to this thesis: the overarching theme of this research is curriculum as comparative and institutional text.⁴⁹ Curriculum reform defined top-down state-mandated changes in the content and organization of what is to be taught.⁵⁰ In this study the rhetoric of reform was studied as *policy as text* using an interpretive lens from 1960 to 2005. Researchers in cross-national comparative education argued for a historical approach to assist a disciplined inquiry and lead to deeper understanding:

Contemporary history is of major importance to contemporary curriculum makers because it enables us to understand and to put into perspective, curriculum initiatives in the past. Studies of curriculum history provide information about past patterns and priorities. They enable us to undertake disciplined inquiry.⁵¹

This study is concerned with science and mathematics subjects in the academic part of the high school curriculum. Goodlad (1984) categorized goals for schooling as academic,

vocational, civic, social and personal and noted that academic goals were perceived by pupils, teachers and parents to be the major goals at all levels of schooling.⁵² The academic part of the high school curriculum has traditionally been the access route to university and higher education. This study considers four subjects in this category: physics, chemistry, biology and mathematics:

The evolution of school subjects is an understudied aspect of curriculum. From a superficial perspective school subjects may be perceived to be stable, immutable, enduring.⁵³

2.5.1 Models of Curriculum Implementation

Curriculum was developed centrally in Ireland and Norway. This means that decisions were taken at departmental level as to what was to be taught, how it was to be assessed and, in some instances, how it was to be taught. Snyder, Bolin and Zumwalt (1992) presented a model of curriculum implementation based on three different designs: the *fidelity perspective*, the *enacted perspective* and the *mutual adaptation perspective*.⁵⁴ While the lines between these may at times be blurred they present three different ideological positions which affect the conception of what constitutes knowledge, the role of the teacher and the process of change. The *fidelity perspective* seeks to research the congruence between the official intended curriculum and the implemented curriculum in the classroom and to locate the factors that hinder or facilitate this process. Knowledge is perceived as originating in outside experts and the process of change is viewed as a linear one. Success is indicated when teachers passively receive the reform and implement it as originally planned. Within the fidelity perspective the socio-cultural context of the school is largely ignored.

The *enacted curriculum perspective* may be regarded as the diametrical opposite of the fidelity perspective. Using this perspective teachers and students move centre stage and are described as curriculum makers. Outside agents are there to provide stimulus while

evaluation is viewed as developmental rather than controlling. Teachers work with the curriculum and an enacted curriculum is developed collectively through professional dialogue. The agents of change are the teachers, and their tacit knowledge is elevated in this perspective, while the role of the external specialist-scholar is underplayed.

The *mutual adaptation perspective* accepts that a curriculum reform will be adapted within the school and recognises the complex socio-cultural milieu within the school. The researcher seeks to identify ways in which the reform is adapted within the system. The agents of change are regarded as an amalgam of external policymakers, management and teachers. Knowledge is found both with external and internal agents of change. The teacher, using this perspective, is indeed a *curriculum maker*, but within the confines of specified national guidelines. This research study most closely resembles a *mutual adaptation perspective*. McLoughlin (2004) argued that mutual adaptation is a necessary step in school-based reform and not an undesirable aberration and contests that reform needs the tacit agreement of management before teachers wholeheartedly engage with the process.⁵⁵

2.5.2 Post-16 Science Education

At the beginning of the 21st century key stakeholders, policymakers and researchers seemed to be in broad agreement that science needed to be taught in new and interesting ways, relevant to the life experience of young people, using innovative teaching methodologies and ICT as a pedagogical tool. If science teaching was to develop a spirit of enquiry and the development of a scientifically literate population then it clearly needed science teachers to become advocates for change. The traditional essentialist epistemology of science education regarded science as a body of facts and the teacher as a subject specialist with expertise to unlock these facts. There was little need for dialogue or debate or connectivity to the socio-cultural world the student inhabited. From the nineteen

eighties onwards new conceptions of science teaching began to be explored and a number of researchers promoted a constructivist model of science education, most notably: Driver and Bell (1986); Sjöberg (2000); Fensham (1988); Osborne (2002); Lemke (1990) and Leech (2005).⁵⁶⁻⁶¹

If a technical-rational approach is used then pure science devoid of application, rich in fact, hypothesis and theory is all that is required. However, if a broader view is shared then science within a socio-cultural context is important as is *science for all*. The last fifteen years have shown the playing out of this debate. Science context and socio-cultural perspectives, as argued by Millar and Osborne (1998), had now firmly entered the agenda:

The science curriculum can appear as a “catalogue” of discrete ideas, lacking coherence or relevance. There is an over-emphasis on content which is often taught in isolation from the kinds of contexts which could provide essential relevance and meaning. Insufficient emphasis is given to showing the tremendous intellectual achievement such ideas represent, and how they have transformed our conception of ourselves and the world we inhabit.⁶²

The STS movement, *Science, Technology and Society*, was introduced in the nineteen nineties and early years of this century and aimed to present science through real life narratives with exemplars from technology and society. A number of new resources were produced to promote the STS approach including the *The Salters Approach* (1990-1992) by the Science Education Department of the University of York.⁶³ While reform in Ireland specified that thirty per cent of each of the science syllabuses at upper secondary was to include STS exemplars it stopped far short of offering an STS approach to the teaching of science. *Information Communications Technology* (ICT) enhanced science learning was also promoted. Data-logging was introduced in Norway in the nineteen nineties and in Ireland in the early years of this century. However, by 2001 OECD findings indicated that the use of ICT as a pedagogical tool in science teaching and learning was not widespread.⁶⁴ Data-loggers as electronic measuring devices, measured a number of variables, including temperature, pressure, pH, and light level, and read experimental

findings directly into a computer giving a real-time graph of the results. The use of data-loggers took the drudgery out of collecting data and drawing graphs and left the experimenter more time to discuss and critically analyse findings. It moved practical work away from lower order into the higher order thinking skills of reflection and analysis.

During the process of completing this research study this researcher had an opportunity to work directly with the national biology support service to support the regional development officers working with teachers. The project resulted in the development of resources and gave an insight into the possibility of teachers as collaborative *curriculum makers* leading learning.⁶⁵ As a partner in a Comenius 2.1 European Commission project for the development of science teachers the researcher had an opportunity to understand the complexity of the reform process and the need for a dialogical approach.⁶⁶

In conclusion reform waves in science education from 1960-2005 charted a change from traditional essentialist epistemologies to more constructivist and eclectic thinking. The reforms invited greater relevance, using an STS perspective, more hands-on experimental approaches and greater use of ICT enhanced learning. Atkin and Black (2003), after a lifetime involved in science education, concluded that the influence of the teacher was of paramount importance to the development of quality school science:

we have come to believe that it is the teacher themselves and their vision, thoughtfulness, beliefs, and abilities that overshadow virtually everything else. It is what they do with students in the classroom that is at the heart of the condition of science education during any period. Do they help students understand the major ideas as well as the evidence that supports them?...Do they create settings wherein students begin to fathom their own capabilities to understand and engage in scientific activity? Do they provide timely assistance as students begin to grapple with complex ideas? In short, do they teach complex scientific phenomena in an intellectually honest manner?⁶⁷

2.5.3 Post-16 Mathematics Education

There is tacit agreement among international mathematics educators that it is important that every student study mathematics as part of a school's core curriculum. According to

Romberg (1992) there is less agreement on what mathematics should be reflected in a school curriculum.⁶⁸ Mathematics education reform in the western world followed a similar story to that of science education reform, changing from a largely essentialist epistemology to more constructivist, problem-solving approaches within a socio-cultural context. This change in philosophy mirrored the change in society at large as it moved from an industrial to a knowledge-based society. Society had less need of a passive and disciplined workforce and greater need for people who were willing to grow, think and work collaboratively in teams.

Research by Boaler (1997), involving three hundred mathematics students during a three year longitudinal ethnographic study, indicated that students did better when teaching was more open and loosely structured.⁶⁹ Girls in higher streams did better when teachers made efforts to assist with communication, linking concepts explicitly and meaning making:

(in one school) the teachers were quite radical in their reconstruction of school mathematics and this seemed to produce an alleviation, or even eradication, of mathematical anxiety and underachievement amongst girls. Importantly, they achieved this by changing the mathematics pedagogy and epistemology, not the girls.⁷⁰

In Ireland in the 1960s, when policymakers wanted students to have access to the beauty of mathematics they mistakenly thought that mathematics with no context would present intellectual fulfilment for all. It was soon realized that beauty was in the eye of the beholder and mathematics with no context did not have mass appeal.

Reforms in the Netherlands through the pioneering work of the Dutch mathematician Hans Freudenthal (1984) introduced relevance and problem-solving into school mathematics, a movement that became popularly known as the RME movement (real mathematics education).⁷¹ The RME movement in mathematics may be compared with the STS movement in science education as both are attempts to bring science and mathematics into real world socio-cultural contexts. Reforms in mathematics education in general suggested a change from transmission of knowledge to stimulation of learning. The focus moved

from a subject-centred classroom, using a transmission pedagogy, to a learner-centred classroom using constructivist pedagogy. Jarowski (1994) argued that using the latter approach mathematics teaching became a highly skilled and time-consuming process:

It is hard work for a teacher to create an appropriate ethos in which mathematical activity and talk take place, and where each person's thoughts are respected; to create activities which encourage pupils own mathematization and its articulation; and to listen and respond to pupils' talk in ways which are designed to achieve the mathematical objectives for a lesson.⁷²

2.6 Teacher Reform and Continuing Professional Learning

The role of the teacher in upper secondary post-16 education, according to the official documentation and research literature, changed considerably in the period 1960-2005. By the end of this study the debate about the extent to which teachers were in fact professionals was being played out in reports (OECD 1998, OECD 2005) and in the international literature: Day (2002); Sugrue (2004) and Darling Hammond (2005).⁷³⁻⁷⁷ Furlong et al (2000) define the professional as a person with a high degree of autonomy, who takes responsibility and works within a collective culture.⁷⁸ Stenhouse (1975) liberated teachers from their role as functionaries of the state through his curriculum development movement in the UK which had a profound effect on thinking across the western world.⁷⁹ The teacher was invited to become an interpreter of curriculum and an architect of change. The connectivity between curriculum reform and teacher development, viewed through the research of Stenhouse (1978) and Skilbeck (1990), led to the formation of a richer conception of teaching including school-based curriculum development.^{80,81}

The role of the teacher was further enhanced in the nineteen eighties through Schön's (1983, 1987) conception of the teacher as reflective practitioner.^{82,83} The changing conceptions of teaching as a professional praxis and the teacher as professional learner were increasingly presented as a panacea for successful change in knowledge societies. By

the end of this research study in 2005 there was no broad agreement within the international literature on the precise meaning of *teaching as a profession*. Although the term was contested there was a growing international research movement progressing this thinking including Hargreaves and Goodson (1996); Fullan (2000); Hoban (2002) and Darling-Hammond and Bransford (2005).⁸⁴⁻⁸⁷

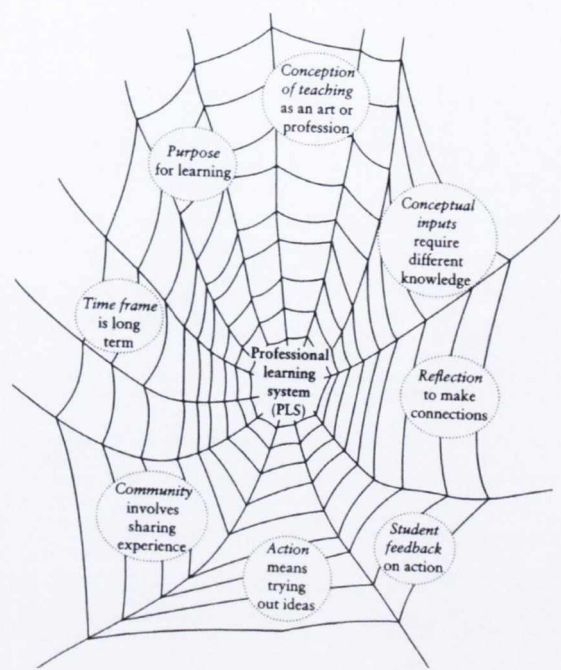
Hargreaves and Goodson (1996) suggest that there are five discourses with regard to teacher professionalism – classical, flexible, practical, extended and complex – and they propose a sixth discourse, post-modern professionalism.⁸⁸ The characteristics of these discourses overlap but they differ in the way they perceive the knowledge-practice relationship. The classical model is based on formal propositional knowledge, residing in experts, and supports a type of professionalism that merely seeks to have clarity with regard to standards of professional practice. The flexible discourse considers the collaborative nature of teaching and focuses on the development of school-based and local learning communities. Knowledge is developed through collaborative practice in local contexts. Practical professionalism construes knowledge as within practice and emphasizes opportunities for reflection and discourse to make tacit knowledge explicit. The extended professional, as opposed to the restricted professional, not only sees their role within their classroom but embraces a community of learners and shares responsibility for development planning and continuing learning. Complex professionalism regards teaching as characterized by high degrees of work complexity with collective planning and many forms of assessment and evaluation.

They suggest a new conception of professionalism which they term *postmodern professionalism* and which displays seven characteristics.⁸⁹ These seven characteristics include increased opportunities to exercise discretionary judgment and to engage with the moral and social purpose of teaching, commitment to collaborative cultures and

heteronomy - where teachers work openly and collaboratively with colleagues - a commitment to care and service, a search for continuous learning and the creation of high task complexity. Hoban (2002) presents this complexity of learning for teachers in his web-like model of what teacher professional learning entailed.⁹⁰ The model shows a myriad of aspects including the need for an action learning approach over a sustained time frame and used to support the conceptual basis of this aspect of the study (Figure 2.4). Darling-Hammond and Bransford (2005) present a separate vision of professional practice through the conception of the teacher working within a democratic community with access to three different types of knowledge: knowledge for teaching, knowledge of the subject and knowledge of learners (Figure 2.5).⁹¹

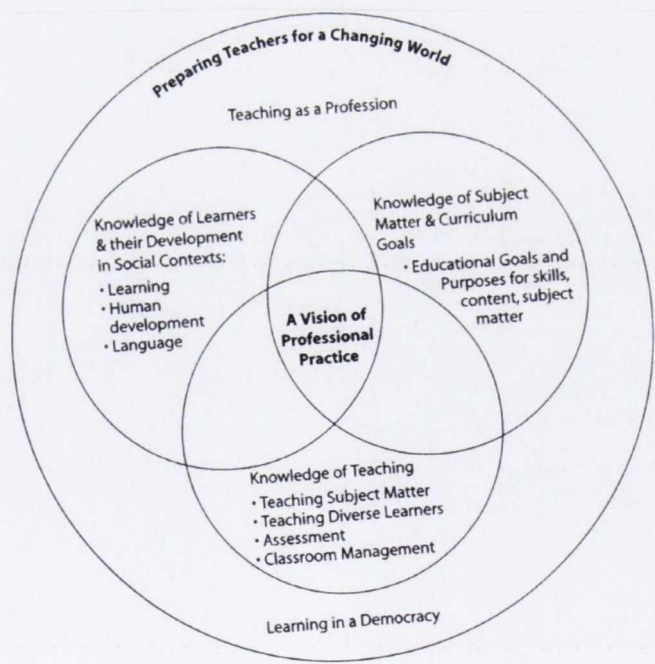
Several large scale school studies show that teachers work best in learning-enriched conditions that favour collaboration and time for teachers to develop as learners. Goodlad (1984) studied thirty eight schools, both elementary and high schools, and presented a picture of the daily reality of teachers' lives as their conditions of work drained energies and promoted routine rather than creative teaching.⁹² Rosenholtz (1991) studied seventy eight elementary schools in Tennessee and identified four social organization variables that related directly to teachers' learning opportunities: shared goals and information between teachers and principals (management) and opportunities for collaboration, evaluation and learning.⁹³ She categorised schools as *learning-enriched*, *learning impoverished* and *moderately-impoverished interfaces* depending on the opportunities provided for teachers to learn. These categories were adapted and used in the exploratory case study research in this thesis (Table 2.1). Knowledge for teaching and the requirement of a specialized knowledge occupied the minds of researchers and policymakers alike from the mid nineteen nineties onwards.

Figure 2.4 Hoban’s (2002) model of teacher professional learning.



Source: Hoban, Garry F. (2002) *Teacher learning for educational change A systems thinking approach*, Buckingham and Philadelphia: Open University Press, 70.

Figure 2.5 Darling-Hammond and Bransford’s (2005) conception of teaching as a professional practice.



Source: Darling-Hammond, Linda and Bransford, John. (Editors) (2005) *Preparing Teachers for A Changing World*, Jossey-Bass, 11.

Cochran-Smith and Lytle (1999) describe a model of teacher education that stretches in a continuum from *knowledge for practice*, to *knowledge in practice* to *knowledge of practice*.⁹⁴ *Knowledge for practice* proposes that knowledge for teaching is formal and resides with experts and is a body of propositional knowledge that teachers need to be told. *Knowledge in practice* proposed that knowledge is constructed by teachers in the contexts of their classrooms and schools through a process of systematic reconceptualisation of their practice. *Knowledge of practice* proposes that knowledge is contested and problematic and focuses on teachers as transformative agents in their social communities where they engage in continuing action learning to generate knowledge from practice. Sugrue (2002) argues that the knowledge-practice relationship may be a blend of aspects of this model.⁹⁵

Edwards, Gilroy and Hartley (2002) suggest that the debate ranges from an objective view of knowledge to a subjective view of knowledge with Schön's model of reflective practice being an alternative model chosen in the absence of other acceptable models of knowledge for teaching.⁹⁶ They suggest a *contextualized model*, which uses a *both-and* approach to knowledge and allows fluidity rather than the more traditional *either-or* conception of knowledge.⁹⁷ In a historical study of the changing paradigms in teacher education, from the 1950s to the 2000s, Cochran-Smith and Fries (2005) propose three different constructs.⁹⁸ They constructed these as *problems*, in the same way that social science researchers use the term *problem* to explore the issues, questions and conditions of a topic of concern to the education community. Teacher education from the 1950s to the 1980s was perceived as *a training problem*, from the 1980s to the 2000s as *a learning problem* and from 1995 to the 2000s as *a policy problem*.⁹⁹ They suggest that all three constructs overlap but that one construct becomes the dominant discourse during the timeframe explored.

Table 2.1 Teachers’ opportunities to learn within the social organisation of schools based on Rosenholtz’s (1991) categories.

Variable	Learning-enriched schools	Learning-impooverished schools	Moderately improverished schools
Formal ongoing information exchange between principal (management) and teachers	Formal mechanisms in place e.g Head of Department/other	No formal mechanism in place e.g Head of Department/other	Some formal mechanism in place e.g Head of Department/other
Formal Opportunities for Collaboration	Time-Tabled and Regular	Not Time-Tabled	Time-Tabled and Irregular
Evidence of Evaluation Culture	Substantive Evidence Ongoing Self-Evaluation/ Peer-Evaluation/ Whole School Evaluation	No Evidence Ongoing Self-Evaluation/ Peer-Evaluation/ Whole School Evaluation	Some Evidence Ongoing Self-Evaluation/ Peer-Evaluation/ Whole School Evaluation
Continuing Opportunities For Teachers’ to Learn	Access to Inservice Education/Teacher Networks/School-Based Curriculum Development	No Access to Inservice Education/Teacher Networks/School-Based Curriculum Development	Some Access to Inservice Education/Teacher Networks/School-Based Curriculum Development

When teacher education was conceived as a training problem teaching was viewed as a technical transmission activity and professional development of teachers was reduced to behaviour modifications. In the 1980s there was a call for well-educated teachers and a *Task Force on Teaching as a Profession* was set up by the Carnegie Forum on Education and the Economy.¹⁰⁰ Efforts were made to codify the professional knowledge base of

teachers and teaching was perceived as an intellectual, decision-making and professional activity. Teachers' ongoing learning was central to this vision:

the emerging agenda (was) to produce knowledgeable professional teachers who were learners, leaders, and school reformers.¹⁰¹

Globalization of the world economy and high achievement gaps among an increasing diversity of pupils led to the construction of teacher education *as a policy problem*. Public interest from the mid nineteen nineties onwards focused on teacher quality and accountability. Studying teacher education as a policy problem proved more difficult. For example, separate studies by Darling-Hammond (2000) and Walsh (2001) reached very different conclusions and their critics cited their separate allegiance to different reform agendas.¹⁰² Nonetheless teacher education programmes serve a number of purposes including improving *teachers' knowledge of subject matter, pedagogy and professional practice*.¹⁰³

Darling-Hammond and Bransford (2005) argue that teachers need to have an awareness of four key areas: knowledge-centredness, assessment-centredness, learner-centredness and community-centredness.¹⁰⁴ They present teaching as high task complexity and use the metaphor of the orchestra conductor to illustrate the layperson's misconception of the simplicity of the profession:

To a music lover watching a concert from an audience, it would be easy to believe that a conductor has one of the easiest jobs in the world. There he stands, waving his arms in time with the music, and the orchestra produces glorious sounds, to all appearances quite spontaneously. Hidden from the audience – especially the musical novice – are the conductor's abilities to read and interpret all of the parts at once, to play several instruments and understand the capacities of many more, to organize and coordinate the disparate parts, to motivate and communicate with all of the orchestra members. In the same way that conducting looks like hand-waving to the uninitiated, teaching looks simple from the perspective of students who see a person, talking and listening, handing out papers, and giving assignments.¹⁰⁵

Teachers' knowledge in the literature encompasses a confusing array of schools of thought, among them positivism, behaviourism, constructivism, social constructivism and

cognitive psychology making what Mumby, Russell and Martin (2001) term the *epistemic puzzle* that underlies teachers' knowledge.¹⁰⁶ Their critique of the literature on teachers' knowledge gives a number of models ranging within Schön's (1983) metaphor of the high ground of theory to the swampy lowlands of practice, including models by Shulman (1987); Carter (1990) and Grossman (1995). Shulman (1987) researched subject-matter knowledge and categorized it into seven categories: *content knowledge*, *general pedagogical knowledge*, *curriculum knowledge*, *pedagogical content knowledge*, *knowledge of learners*, *knowledge of educational contexts* and *knowledge of educational ends*.¹⁰⁷ His work was critiqued by Sockett (1987) and found wanting based on the lack of a moral framework for teaching.¹⁰⁸ Carter (1990) identified three frames for learning to teach: *information processing*, *practical knowledge* and *pedagogical content knowledge*.¹⁰⁹ Pedagogical content knowledge, from Shulman's (1987) research, included what teachers' know about their subject and how this knowledge is translated into classroom curricular events. Grossman (1995) presented a typology of teacher knowledge that included six domains: knowledge of content, knowledge of learners and learning, knowledge of pedagogy, knowledge of curriculum, knowledge of context and knowledge of self.¹¹⁰ The changing conception of the teacher as professional learner suggests that opportunities need to be provided for collaboration and reflection. It is these process and organizational issues that this thesis is concerned with and to which we will now turn.

2.7 Substantive Dimensions of Process and Organisation

This research study, at both national and school level, was problematised using the dimensions of process and organizational issues. Process issues were concerned with pedagogy, assessment and evaluation within teaching as a professional praxis. Organisational issues considered the structures, facilities and resources made available and opportunities provided for teachers to engage in a collaborative praxis.

2.7.1 Process Dimension

By 2003-2004 the official documentation espoused teachers' following an experiential learning approach with in-built reflection to ensure higher levels of engagement and relevance for the learner. Teachers were being asked to relinquish their teacher-led approaches to teaching and to develop a learner-centred approach. The teacher was being invited to ensure learning was tailor-made for the diversity of learners and to conduct post-lesson appraisals both individually and collectively in a type of evaluation that involved both self-evaluation and peer-evaluation practices.

2.7.2 Pedagogy

The progressive movement in teaching and learning may be traced back to Dewey (1938) who advocated an experiential and reflective approach to teaching for learning.¹¹¹ This model of teaching was further developed by Friere (1970) who suggested that new knowledge was not learned by transmission - the *banking conception of knowledge* - but by construction from older knowledge in a process of transformation unique to each individual.¹¹² This thinking was further expanded through the conception of the learning cycle of Kolb (1983) who suggested that there were four different types of learners: theoretical learners, pragmatic learners, reflective learners and innovators.¹¹³

Pedagogy is concerned with teaching and learning and suggests their interconnectedness. Lingard, Hayes and Mills (2003) argue that these three components, curriculum, pedagogy and assessment, are inextricably linked and that pedagogy needs to become a central focus of educational policy.¹¹⁴ Their research findings from over one thousand classrooms in Queensland, Australia, the productive pedagogies model, indicates that to improve student learning outcomes there is a need to value teachers, their knowledge and ongoing professional learning, and to underpin their professional praxis with systemic and structural supports to assist the development of a culture of learning within schools. It

envisages a form of teaching and learning that places the teacher in the role of public intellectual in the production of pedagogical knowledge. Quality teaching is also concerned with the qualification of teachers in their specific subject specialism.¹¹⁵

2.7.3 Assessment

Research on assessment focused on the need for teachers to engage in dialogue with each other, and with their students, so that the process had formative as well as summative dimensions. Assessment was no longer seen as something done to the student by the teacher. Black and Williams (1998) identified this as the difference between assessment of learning and assessment for learning.¹¹⁶ The focus on assessment for the promotion of learning was on the presence of ongoing feedback loops through a dialogical process.

2.7.4 Evaluation

Policy documents espoused the need for teachers to become critically reflective and to engage in a type of self-evaluation and peer-evaluation within the school as well as external evaluation by the agents of the state, be they inspectors or the local directorate of education. Brookfield (1995) highlights the need for teachers to become critically reflective and suggests they needed to use four lenses to achieve a fuller perspective and feedback on their teaching for learning.¹¹⁷ He recommends the lenses of self-evaluation, peer evaluation, student evaluation and the lens of the literature. Mumby, Russell and Martin (2001) argued that serious reflection and the construction of professional knowledge by teachers' was not so much an issue of time as it was of perspective:

(If the school does not) encourage, support and reward reflection and experimentation by teachers and by students, then we have little hope of overcoming the challenges that school contexts present to the development of professional knowledge within teacher education.¹¹⁸

This research study examined evaluation from the macro context of systems of evaluations introduced through national reforms, the opportunities provided inside the case study schools for teachers to meet and the extent to which science and mathematics teachers

claimed they were engaged in a formal process of evaluation. Informal approaches to evaluation were not considered in this study.

2.7.5 Organisational Dimension

Organisational issues considered the structures, facilities and resources for both the state-mandated reforms in science and mathematics and the reforms as implemented in the case study schools in both countries. This included the structural and organizational changes made to facilitate teachers teaching in new and innovative ways: pre-preparing their class material and having formal regular access to colleagues for ongoing development planning and evaluation. Lynch (1999) contested that access to professional dialogue for teachers is a significant indicator of a partnership approach in curriculum reform:

The absence of dialogue in pedagogical practice presents learning as a top-down rather than a partnership process; it presents the learner as passive and subordinate, thereby reinforcing hierarchy which is anathema to the principle of equality itself.¹¹⁹

The structure dimension considered structures and scaffolds provided by school management to assist the curriculum reform process in science and mathematics. Were there subject departments and heads of departments? Were budgets assigned? The presence of some of these practical items indicates, as argued by Hargreaves and Hopkins (1991), a school-based response to the policy process:

These include not only the teaching-learning activities used in the school, but also the school's procedures, role allocation and resource use that support the teaching-learning process (in our words the school's management arrangements)..... although the school is the centre of change it does not act alone. The school is embedded in the education system that has to work collaboratively and symbiotically if the highest degrees of quality are to be achieved.....ideally top-down provides policy aims (are) complemented by a bottom-up response.¹²⁰

Hargreaves (2003) argues that the knowledge society runs *not on machine power, but on brain power – the power to think, learn and innovate.*¹²¹ Teaching to the test diminishes the scope and flexibility of teachers as curriculum makers and shapers and may result in less time for creative and critical thinking, *prized features of the knowledge economy.*¹²²

According to Hargreaves (2003) much depends on teachers' working conditions and environments especially what he terms *the tyranny of time*.¹²³ In his opinion learning communities in schools need to gather data to evaluate progress on an ongoing basis.¹²⁴

Successful and sustainable change requires time for teachers to understand it and integrate it into their practice. Similarly, for change to be successful and sustainable, it needs a prudent focus on a manageable number of key priorities rather than scattered attempts to change everything; as well as necessary support of sufficient resources, quality learning materials and adequate professional development.¹²⁵

Stoll, Fink and Earl (2003) highlight the issue of time with respect to the teacher as a professional learner.¹²⁶ They argue that learning is cognitive, social, emotional, non-linear and erratic. They regard the cellular organization of schools, one teacher-one class, to be the single greatest impediment to promote teacher learning, and therefore student learning, and suggest that this conception of schools is being challenged:

The standard organization of schools with classes lasting a set number of minutes and 25-30 pupils in a room with a single teacher severely limits the ways in which time can be allocated and used. Over the years we have observed many innovative strategies for changing the nature and experience of time in schools.¹²⁷

2.8 Refining the Theoretical Framework for the Study

The literature review involved an in-depth study of the policy process at both macro- and micro-levels across a range of areas that included cross-national comparative studies, pedagogical, organisational and teacher reforms and science and mathematics education. This selection from the international literature gave a number of theoretical frameworks that fitted well with the main research focus for the study (Table 2.2). These frameworks were selected based on their prominence in the literature and their applicability to this study. The frameworks in this selection had considerable overlap between the different authors and researchers. These were studied in greater depth and further refined. The outcome of this process was the development of a novel theoretical framework for the data

analysis in this study (Table 2.3) This framework provided a detailed map of various factors relating to the policy process, in the context of a cross-national comparative study.

Therefore this thesis considers that aspect of the policy implementation process where policy bridges the boundary between *policy as text* and policy as *professional praxis*, Bowe, Ball and Gold (1992).¹²⁸ It is at this initial interface, as the documentation is adapted and owned by management and teachers, that this study is situated. The study inquires into two aspects of the policy process, adapted from O’Buachalla’s (1988) dimensions, organisational structures and supports and a range of process issues.¹²⁹ The overarching theme of the study involves *curriculum as institutional and cross-national text* as argued by Pinar et al (2002).¹³⁰ Within this overarching theme three sub-themes divert the focus of the study to *organisational structures and supports*, *pedagogy and assessment* and *teaching as a professional praxis*. The first sub-theme concerns *organisational structures and supports*. These are considered through the lens of Rosenholtz’s (1991) criteria which envisage the school as a social learning organisation and a place where teachers, in addition to students, are conceptualised as learners.¹³¹ The four criteria focus on continuing professional learning in an evaluative culture.

The second sub-theme concerns *pedagogy and assessment*. Throughout the twentieth century there was generally silence with regard to pedagogy, especially for older academic subjects like mathematics and science. This change was brought about by an eclectic use of a range of learning theories, from behaviourism to constructivism to connectivism, the increasing diversity of the learner, and the new post-PISA emphasis on the need for higher order critical thinking and self-directed learning in a knowledge society. Teacher professional knowledge was becoming recognised as containing a multiplicity of aspects, including subject knowledge, pedagogical content knowledge and knowledge of, in and

for practice. A large scale synthesis of research in New Zealand, the Alton-Lee Report (2003), attempted to synthesise the salient characteristics of a pedagogical praxis.¹³² These characteristics included teaching for self-regulated learning and critical thinking and teacher collaboration and reflection enabling synergies around improving teaching. The conceptual basis for this aspect of the study was the *productive pedagogies model*, argued by Lingard et al (2001), which seeks to value teachers and put their pedagogical practices at the heart of the educational policy process.¹³³ This conception needs to be fully supported by structural reform and systemic supports:

There is a need to value teachers, their knowledge and ongoing learning (see Darling Hammond, 2000) as central to a school's organisational capacity, as well as being a central rationale for systemic infrastructural support for schools.¹³⁴

The third sub-theme concerns *teaching as a professional praxis*. This was juxtapositioned between one movement focusing on taming and controlling teachers and a separate movement seeking to expand the boundaries and responsibilities of teaching. This sub-theme was conceptualised using the *post-modern professional* model put forward by Hargreaves and Goodson (1996).¹³⁵ This conception focused on the task-complexity of teaching and the need for pre-planning, collaboration and evaluation.

Vertical models of reform, whether top-down or bottom-up, were failing to produce deep change of practice by the 2000s. More horizontal models, with key actors pooling and sharing their various levels of expertise, were beginning to enter the professional learning literature. Wenger (1998) argued for the development of communities of practice while Engeström et al (1995) conceptualised activity theory to better understand boundary crossing between learning communities.^{136,137}

In summary the three sub-themes collectively represent various aspects of the paradigm of teaching for learning, in science and mathematics, through consideration of the reforms

through a range of lenses based on the sub-themes. These three sub-themes included pedagogy and assessment, organizational structures and supports and teaching as a professional praxis. They may be stated as follows:

1. **Pedagogy and Assessment:** This sub-theme considers the pedagogical practices recommended in the reforms in science and mathematics upper secondary academic education. It is related to teachers' everyday work and inextricably links teaching, learning and assessment for the development of a culture of learning.
2. **Organisational Structures and Supports:** This sub-theme suggests that the new learning paradigm, recommended in the science and mathematics reforms, requires different organisational structures and supports at the level of the school – facilities, resources, teacher-teacher meetings times – than was required for previous reforms that supported more teacher-centred forms of schooling.
3. **Teaching as a Professional Praxis:** This sub-theme regards the teacher as a professional learner, within a post-modern conception of the teacher as professional, and recognises the need for teacher collaboration, pre-preparation for teaching for individual need, teacher evaluation, both self-evaluation and peer evaluation, and opportunities for teacher continuing learning and education.

2.9 Chapter Two: Summary

The flow chart for the international literature review explored the complexity of change, the value of a cross-national comparative study, conceptions of the policy process and curriculum reform. What emerges from this is a theoretical framework for the study and three sub-themes that connect pedagogical, organisational and teacher reform. The unifying theme with respect to each of these is the conception of *curriculum as institutional and cross-national text*.

Table 2.2 A selection of the literature underpinning this study.

	Literature Reference	Main Features
Cross-National Comparative Study	Kohn (1989) Pinar (2002) Crossley & Watson (2003)	Curriculum as Institutional and Cross-National Text Nation as Unit of Analysis While Similarities may be interpreted across nations Caution needs to be exercised with Differences Sensitivity to Context & Culture
Macro-Level Official Policy Analysis	Fullan (2000) Hoban (2002) Wellington (2000) Bowe, Ball and Gold (1992) O’Buachalla (1988)	Clarity of Goals & Means Complexity of Teacher Learning Interpretive Lens Policy as Text Policy as Professional Praxis Process & Organisational Dimensions
Micro-Level Analysis Case Study Analysis	Snyder, Bolin and Zumwalt (1992) Tamir (2004) Yin (1995)	Mutual Adaptation Model Management and Teachers not naïve readers Exploratory Case Study
Pedagogy & Assessment in Science & Mathematics	Lingard et al (2001) Black & Williams (1998) Driver & Bell (1986) Jarowski (1994)	Teaching for Learning Assessment for Learning Inquiry Stance ICT-Enhanced Learning
The Changing Role of the Science & Mathematics Teacher	Bowe, Ball and Gold (1992) Monsen (2003) Hargreaves and Goodson (1996) Cochran-Smith and Lytle (1999) Brookfield (1995)	Policy as Professional Praxis Epistemology of Teachers Post Modern Professionalism • Discretionary Judgment • Collaboration • Planning Knowledge for praxis Knowledge in praxis Knowledge of praxis Evaluation for Learning
Organisational Supports & Structures	Stoll, Fink and Earl (2003) Hargreaves (2003) Rosenholtz (1991)	Formal Time for Teacher Learning Collaboration & Ongoing Learning Formal Structures Resources

Table 2.3 The theoretical framework for data-analysis in this study.

Theoretical Model	Characteristics			
Pinar et al (2002)	Overarching theme	Curriculum Reform as institutional text	as cross-national text	similarities and differences between nations
Snyder, Bolin and Zumwalt (1992)	Lens of school-based adaptation	The mutual adaptation model of curriculum implementation	Management and teacher bring their own interpretations to policy	Policy text is reflected through these interpretations and adapted accordingly
Bowe, Ball and Gold (1992)	Lens of key landscapes	Policy as text Policy as praxis	Macro-landscape	Micro-landscape
O’Buachalla (1988)	Lens of key dimensions	Substantive dimensions of the policy process	Organisational structures and supports	Process Issues Pedagogy Assessment and Evaluation
Rosenholtz (1991)	Sub-Theme 1 Paradigm of teaching for learning	A model of the school as a social organisation	Four criteria for the teacher as learner	Formal structures opportunities for learning evaluation inservice education
Lingard et al (2001)	Sub-Theme 2 Paradigm of teaching for learning	Productive pedagogies model	Teacher as learner at the centre of education policy	Self-directed learning and critical thinking
Hargreaves and Goodson (1996)	Sub-Theme 3 Paradigm of teaching for learning	Post-modern professional model of teaching	Complexity of task	Collaboration and evaluation

The literature review and this study acknowledge the complexity of change and the complexity of teacher professional learning. Some of the advantages of a cross-national comparative study identified include:

- It gives a broader perspective than may be found in one country only.

- This broader perspective gives an enhanced opportunity to extend the frontiers of knowledge and extend theories of the phenomenon under study - in this case the policy process as it applies to science and mathematics education.
- It helps raise critical policy questions about the role of the state as well as the role of the school in the policy process.

In this study the policy process is viewed through the adapted model of Bowe, Ball and Gold (1992) as *policy as text* and *policy as professional praxis*.¹³⁸ Each of these in turn is viewed through the adapted dimensions of O’Buachalla (1988): the *process and organizational dimensions*.¹³⁹ The *mutual adaptation model* of Snyder, Bolin and Zumwalt (1992) is used as the policy implementation model inside the schools as it recognises that management and teachers are not merely naïve readers of *policy as text* but that they bring their own wisdom, insights and experience with them as they engage with this text.¹⁴⁰ Reforms in science and mathematics education indicate a move from traditional essentialist epistemologies to more eclectic epistemologies. Both subject areas are required to be taught using an inquiry stance, ICT-enhanced learning, more constructivist approaches to teaching and learning and more real world exemplars using either *Science, Technology and Society* or *Real World Mathematics* approaches.

Rosenholtz (1991) studies the social organization of school and the conditions required for teachers to learn.¹⁴¹ She identified that in *learning-rich environments* there was a formal mechanism for dialogue between management and teachers, opportunities for collaboration that were time-tabled and regular and substantive evidence of the development of an evaluation culture with teachers having opportunities, both in-house and externally, for continued learning. Process and organizational issues were considered in both the macro and micro aspects of this study. Process issues were concerned with pedagogy, assessment and evaluation. Lingard et al (2001) presented the *productive*

pedagogies model for teaching for quality learning and the role of the teacher as public intellectual in the production of pedagogical knowledge.¹⁴² Teacher reform as a *professional praxis* focused on developing a culture of teaching for learning and meeting individual need. This raised questions about the *knowledge-practice* relationship and requirements for developing collaborative and reflective cultures. Hargreaves and Goodson's (1996) model of post-modern professional was used with its emphasis on the teacher as a continuous learner engaged in a reflective and collaborative praxis.¹⁴³

Chapter Three: Research Design and Methodology

This study is first and foremost a cross-national comparative research study taking the macro- and the micro- policy process into consideration. This presents the researcher with several dilemmas that need addressing in the rationale and design of the research study. Are the findings going to be generalisable? Will the findings generate some new theory or enhance the existing theoretical knowledge base? How is the research going to be sensitive to context and culture while the researcher is an *insider* in one country and an *outsider* in the other country? Where is the researcher positioned in terms of epistemology? What ontological values need declaring? How is the researcher going to be *rigorous, critical and objective* in the handling of data so that the findings are deemed to have validity and be reliable?¹ How is the researcher going to ensure that ethical guidelines are followed? What are the limitations of the study? Chapter Three seeks to answer these questions through consideration of the research questions, the research rationale, the research design, the research methodology chosen, the reliability and validity of findings, the ethical guidelines followed and the limitations of the study.

3.1 Background and Context

This research study seeks to track changes in science and mathematics reforms in high school as they move from the state-house to the school-house. The study is exploratory and seeks to ascertain similarities and differences and the extent of congruency between the rhetoric of *policy as text* and the reality as *policy as professional praxis*. It is a direct step from the theoretical framework to improving the research questions, and identifying the sampling frame and methodology. Generating the key questions however is an iterative process that was returned to regularly in the course of the study, each iteration helping to further clarify the thinking behind the complexity of the topic under study:

Formulating the questions is an iterative process, the second version is sharper and leaner than the first, and the third gets the final few bugs out.²

This cross-national comparative research study uses a mixed method approach. The study uses a triangulation of methods, an official document and statistics search at national level in both countries and case study research in ten schools, five in each country. The research uses both quantitative (QUANT) and qualitative (QUAL) methods and as a research philosophy most closely resembled the mixed methods approach of Tashakkori and Teddle (1998, 2003).^{3,4} They propose the complementarity of QUAL/QUANT methods and conceptualise that subjective-objective are along a continuum rather than diametrically opposed. The research findings from the official documents (*policy as text*) gave the course grain for the study while the fine grain detail is found in the case study research (*policy as professional praxis*) in the context of the schools. The case study method is sympathetic to the interpretive paradigm, giving important insights into the school-based policy process:

Case study material in this sense can provide powerful human-scale data on macro-political decision-making, fusing theory and practice.⁵

The research plan involved selection of appropriate research methodology and consideration of all aspects of quality control, reliability and validity of data collection and data analysis, and ethical guidelines. It is with the framing of the research questions that we begin this process.

3.2 Research Questions

The focus of the study was on the policy process as it moved from the state, through official documents, into the school and was received by management and teachers. The six key questions driving both macro- and micro- levels of the study, in both countries, may be stated as follows:

Q1. What can be learned from a historical study of the macro policy process and from a study of the micro policy process in 2003-2004?

Q2. How were the reforms in school organizational structures and supports changed between 1960 and 2005 and how were these refracted inside the schools in 2003-2004?

Q3. How were the key curricular and pedagogical reform waves in science and mathematics education changed in the 1960-2005 time-frame?

Q4. What was the changing role of the teacher and changing opportunities for continuing professional learning in the 1960-2005 time-frame?

Q5. How were these policy reforms, in science and mathematics, perceived inside the schools by management and teachers in 2003-2004?

Q6. What can be learned from a study of the graduation rates in science and mathematics and the changing number of schools and teachers at national level and the school profile, teacher profiles and uptake in the sciences and mathematics in 2003-2004 in the case study schools?

3.3 Research Rationale

By the late nineteen eighties three different philosophical views of education research, positivist, interpretive and critical, described by Sparkes (1992), had become established.⁶ Certain assumptions with regard to *ontology* and *epistemology* were at the heart of each philosophy. Ontological assumptions are concerned with the nature of the subject matter and question whether the *reality* to be investigated is external to the individual or the product of individual cognition. Linked to this are questions concerning the epistemology or nature of knowledge. Is knowledge hard, real and capable of being transmitted (an objectivist epistemology) or is it softer, more subjective, based on experience and insight of an essentially personal nature (a subjectivist epistemology)?

The positivist paradigm, and more recently the post-positivist paradigm, represents a quest for objectivity using the scientific method of inquiry common to the natural sciences. The researcher behaves as a detached observer and believes that knowledge is totally independent of the researcher and indeed independent of the socio-cultural context. This researcher is often attracted to large scale quantitative studies. The ontology underpinning

the positivist paradigm is that reality is external to the researcher. The epistemology embraced is therefore objectivist. The interpretative paradigm stands in direct contrast to positivism and includes a range of research traditions, including phenomenology, ethnography, hermeneutics, constructivism and case study research. Efforts to minimize researcher bias are important and this is achieved through a subjective objectivity process that involves the researcher in a reflexive and systematic reflective study of their own biases. This researcher is often attracted to qualitative interpretive studies set within their socio-cultural context. Reality is mind-dependent and the knower and the process of knowing cannot be separated. The ontological position is internal-idealist and relativist. The epistemology embraced views knowledge as subjective and interactive. The critical paradigm is an ideologically oriented inquiry with many diverse strands, such as, feminism, freireism and neo-marxism, all leading to a number of critical theories.

The critical theorist believes that policy is made by those in society who wish to remain in power through social class and other privileges and engages in a critical interpretation of aspects of education from this vantage point. The central intention of critical theory is emancipation enabling people to be in control of their own lives. Reality is considered to be socially constructed and knowledge is seen as context specific and value-laden. The ontology of the critical paradigm may be either external-realist or internal-idealist. Epistemology is both subjective and interactive.

No one way of knowing appears to provide all answers and it is becoming more acceptable to respect different paradigms in a spirit of intellectual curiosity:

As we approach the twenty first century we need to cultivate such open-minded scholarship and encourage a pluralistic stance that recognizes that there is no single, legitimate way to make sense of the world.⁷

Some researchers have moved toward mixed methods placing themselves along a quantitative-qualitative spectrum. Tashakkori and Teddle (2003) suggest that this paradigm counters the incompatibility theory:

On a philosophical level, mixed methodologies had to counter the incompatibility theory, which was predicated on the link between epistemology and method. To counter this paradigm-method link Howe (1988) posited the use of a different paradigm: pragmatism. A major tenet of Howe's concept of pragmatism was that quantitative and qualitative methods *are compatible*.⁸

Ercikan and Roth (2006) also propose an integrated approach to research inquiry and they argue that modes of inquiry should reflect the type of research questions posed.⁹ Mixed methods research uses multiple approaches and presents an opportunity to offset the limitations of one method through employing the strengths of another:

It is an expansive and creative form of research, not a limiting form of research. It is inclusive, pluralistic, and complementary, and it suggests that researchers take an eclectic approach to method selection and the thinking about and conduct of research.¹⁰

Using a moderate relativistic epistemology, one that justifies the value of knowledge from many sources rather than elevating one source, does not require the researcher to ignore that different approaches are supported by different epistemologies. Rust et al (1999) in an extensive literature search of the peer-reviewed articles in well known comparative journals noted that most studies do not detail their data collection or data analysis methods.¹¹ However they did note the congruency between philosophical underpinnings and researchers positions with respect to the epistemology of knowledge production and their ontological values:

Ontologically speaking, quantitative researchers tend to argue that reality is objective and singular, existing apart from the researcher, while qualitative researchers tend to see reality as being subjective and multiple. Epistemologically speaking, quantitative researchers tend to claim that they are outside their sphere of research, while qualitative researchers tend to believe that they are continually interacting with the subject matter being researched. Axiologically speaking, quantitative researchers usually claim that they are operating in a value-free and unbiased fashion, while qualitative researchers usually believe their values and biases come into play in their research activities.¹²

Rust et al (1999) recognized that these paradigms only fully come into play at the extremes of the qualitative/quantitative continuum. Their review indicated that the comparative field was mostly shaped by qualitative studies although these were often supplemented by quantitative statistics. Comparative researchers generally appear to rely heavily on a qualitative orientation and on similar philosophical assumptions:

Concerning the nature of reality, comparative educators would tend to see reality as somewhat subjective and multiple, rather than objective and singular.

Epistemologically, comparative educators would tend to interact with that being researched rather than acting independently and in a detached manner from the content. Axiologically, comparative educators would tend not to see research as value free and unbiased; rather they would accept the notion that their research is value-laden and includes the biases of the researcher. We must stress, however, that the distinction between qualitative and quantitative analysis in the field does not begin to extend to the extremes of these two paradigms. Even with such an overwhelming tendency toward qualitative research, it is also clear that quantitative studies play a minor though important role in the field.¹³

Cohen, Manion and Morrison (2000) argue that blue skies research may be used to gain a better understanding of the complexity of the phenomenon under study:

(this) "blue skies" research....is open-ended, exploratory, contributes something original to the substantive field and extends the frontiers of knowledge and theory.....The researcher wants to advance the frontiers of knowledge of phenomena, to contribute to theory and to be able to make generalizations; (whereas) the evaluator is less interested in contributing to theory or a general body of knowledge.¹⁴

This study uses a type of exploratory and holistic evaluation recommended by Hamilton (1976) and described by him as *illuminative evaluation*:

Holistic evaluation seeks to portray an education programme in its entirety. Illuminative evaluation (as this is the terms that occurs most frequently) seeks to open out an educational situation to intelligent criticism and appraisal.¹⁵

Given that ultimately all research calls for professional judgment the researcher needs to be open and reflexive about their own thinking, biases and personal theories:

At root, evaluation is about valuing and judging.....determining the standards against which a program will be judged is a contested task....program effectiveness, for example, has many hues, depending on one's vantage point in both space and time.¹⁶

Research studies of policy have the potential to influence the policy process although this democratic ideal cannot be guaranteed:

Policy-making is multidimensional and multifaceted. Research is but one (and often minor at that) among the number of frequently contradictory and competing sources that seek to influence what is an ongoing and constantly evolving process.¹⁷

The policy researcher needs to understand the policy process is fraught with contestation about meaning and ideological values:

The trajectory perspective attends to the ways in which policies evolve, change and decay through time and space and their incoherence. Hence policy-making is a process which takes place within arenas of struggle over meaning.¹⁸

Inside the school management and teachers are significant policy gate-keepers. Their ownership of the spirit of the reform is a *sine qua non* of the reform process.

3.4 Research Design

Comparative education draws from a range of research methodologies to answer the questions posed:

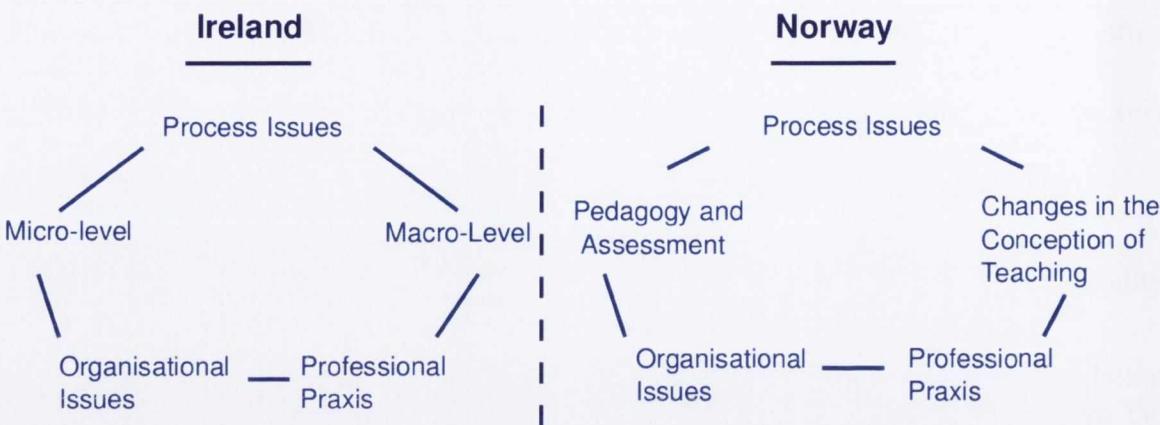
Comparative educators are free to draw on those methods of inquiry that seem most appropriate to them to answer the research questions that have been posed.¹⁹

The macro- and micro- levels of this study were finally brought together in a comparative illuminative evaluation (Figure 3.1). This gave an opportunity to identify key similarities and differences between the systems, engage in theory extension, raise critical questions about the policy process and suggest some areas for further research.

3.5 Research Methodology

The methodology chosen involved three separate aspects (a triangulation of methods) including: an official document search at the macro level, case study research in ten schools and a reflexive and reflective study by the researcher. The macro study considers policy as text and the case study research represented policy as praxis.

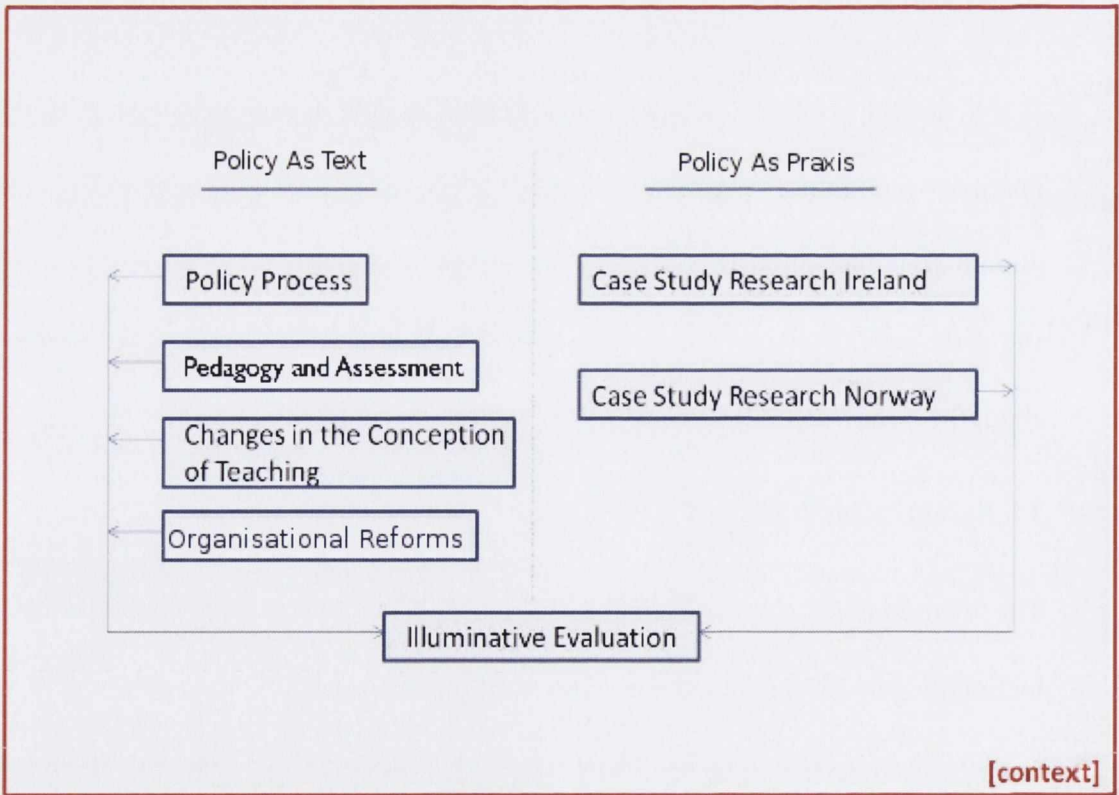
Figure 3.1 The research design for the cross-national comparative study.



Source: Author.

Findings from both sides of the research plan were then interpreted to yield a better illumination of this aspect of the policy process (Figure 3.2).

Figure 3.2 The research methodology plan for the study in context.



Source: Author.

Data gathered during the research study included interview transcripts, questionnaires, policy documents, field-notes and personal reflections. Collectively they gave a holistic picture of the policy process:

While each technique can be studied and practiced in itself, in the real world of case study research, interviewing, observing, and examining documents merge in the process of understanding and describing the phenomenon of interest.²⁰

3.5.1 Theoretical Generalisation

According to Evans (2000) theory shows how things are connected and is the intellectual capital that connects the particular to it's context:

(it) summarises and organises knowledge by proposing a general relationship between events.²¹

Eisenhardt (2002) considers the process of building theory from case study research and suggests a few fundamental approaches that need to be adopted including: defining the research questions, using theoretically useful cases, multiple data collection systems, flexible data collection methods within case and across-case analysis and comparison with literature.²² While research studies of this scale generally do not generate new theories in the same way as a large scale research study often does, they carry the potential, according to Mabry (2008), of refining existing theory and pushing out the boundaries of knowledge in the field.²³

In the process of furthering knowledge Phelan and Reynolds (1996) argue that deductive and inductive reasoning interact in various ways.²⁴ A balanced approach to furthering knowledge comes from combining both in a *hypothetico-deductive method*. This method is an approach to research that involves both deductive and inductive reasoning. It often begins with a hunch or conjecture which might be a response to an event or a spark of imagination. The next stage involves using deductive reasoning to generate a hypothesis which may be testable. To test this hypothesis the researcher attempts to establish whether

it is borne out by the evidence. The results of the test will have implications for the original conjecture which is then evaluated accordingly.

Kohn (1989) argues for cross-national comparative studies by reminding us that they are useful for testing or extending theory.²⁵ They are useful to establish the validity of interpretations derived from single-nation studies and are especially valuable for forcing a revision of interpretations to take account of inconsistencies that could never be uncovered in single-nation research. He argues that while cross-national similarities lend themselves readily to interpretation, cross-national differences are much more difficult to interpret.²⁶ Even ruling out differences in methodologies the scope of their interpretation has to be curtailed. However they can raise critical questions that might never surface if the study was conducted in one country only.

3.5.2 Official Document Search

The official document search in both countries focused on tracking the main policy reforms in science and mathematics in upper secondary from 1960-2005 from consideration of official documents in curriculum reform, school development and teacher development. The official search included both documents and official statistics for the period under study. The documents included sources from the Ministry of Education in both countries and related sources from support services, educational agencies and some national research reports. Gaining an understanding of the macro landscape involved a desk and archive study of evidence from official documents, peer-reviewed journals and national banks of statistics. The material was perused from 1960 to 2005, to gain a more complete picture of the reform impulses in science and mathematics in the academic part of upper secondary education in both Ireland and Norway:

Texts are of importance for qualitative research because, in general terms, access can be easy and low cost, because the information provided may differ from and

may not be available in spoken form, and because texts endure and thus given historical insight.²⁷

This part of the study researched official policy documents such as government publications and parliamentary reports in Ireland (*Dáil Eireann*) and Norway (*the Storting*). The comparative aspect of the official document search was facilitated by access to documents in both Ministries of Education, in Ireland and Norway, through the internet.²⁸ The use of such an extended timeframe helped give the *policy as text* study a deeper description:

The investigative impulse that leads to a search for evidence is prompted by some form of puzzlement....it is easy to forget that the historical data collected for analysis are defined as *relevant* by the form of puzzlement that exists in the researcher's head.²⁹

In Ireland, for example, there were documents emanating directly from the Ministry (syllabuses and chief inspectors' reports) and documents from the statutory body the *National Council for Curriculum and Assessment* (NCCA) but there were also a range of documents with the *Department of Education and Science* (DES) logo which were produced by the support services, at one remove from the Ministry, albeit under the watchful eye of the Inspectorate:

Questions regarding the authenticity of a document often arise in the research arena. Such questions are, of course, essential – and they often shed light on important issues concerning the reliability of text as evidence.³⁰

The aim of this part of the study was to ascertain the extent to which Fullan's (2000) *clarity of goals* was applicable, to indicate similarities and differences in the reforms in both countries and to identify any patterns emerging.³¹ The long timeframe gave an opportunity for some historical insights to emerge:

The process of broad generalization is thus not simply inductive: it remains an act of creative and often normative interpretation, within the limits established by the evidence. To a considerable degree, history remains stubbornly subjective.³²

This part of the study was supplemented by statistical data compiled by the author from a number of official databases. This minor yet significant quantitative dimension of the study was further facilitated by the fact that the populations of Ireland and Norway were similar. This interpretation of official policy documents was guided by the argument of Wellington (2000):

Documentary research starts from the premise that no document should be accepted at face value, but equally that no amount of analysis will discover or decode a hidden, essentialist meaning. The key activity is one of interpretation rather than a search for, or discovery of, some kind of Holy Grail.³³

3.5.3 Case Study Research

Case study research is used, according to Yin (2003, when a *how* or *why* question is being asked about a contemporary phenomenon over which the researcher has little or no control.³⁴ It's use is in a desire to better understand a complex social phenomenon, in this case, the policy implementation process. In this school-based part of the study the dominant question is a *how* question:

How is the policy implementation process mutually adapted inside the school through consideration of: the organizational reforms, the perspectives of the management and teachers and the uptake of the sciences and mathematics in 2003-2004?

This question gave rise to key research questions that drove the case study research. The case study method takes into account contextual conditions that may be pertinent to the phenomenon under study. For example in this case study these included, such factors as, the range of organizational supports the school was adapting to underpin the reforms and the congruency or dissonance between the perspectives of management and/or the perspectives of the teachers. This research strategy relies on multiple sources of evidence (questionnaires, interviews, field notes, observations) all converging in a triangulation to give a rich description of the phenomenon under study. It is concerned with the rigorous and fair presentation of empirical data. Therefore as a research method, case study

research, is underpinned by pre-specified systematic procedures which collectively assure the reliability and validity of findings (see section 3.6 for the full range of validity tests applied in this study).

It is necessary to distinguish case study research from qualitative research methods, such as ethnographic studies or participant-observation studies. For example, ethnographic studies involve a detailed close-up observation of the real world, often over an extensive time-period, without prior commitment to a theoretical model. Case study research, unlike qualitative research studies, often uses a range of data collection strategies including quantitative as well as qualitative approaches. In this study quantitative data was obtained through questionnaires, including such data as school profile, teacher profiles, organizational profiles and student uptake in the sciences and mathematics.

The case study design in this study was planned on the basis that it was an exploratory case study, capable of adding real life context to the archival study and illuminating the *mutual adaptation curriculum reform process* in five schools in each country. The data generated, from this multiple case study, would illuminate the school-based policy process through presenting some similarities and differences found within and between schools, raising some critical questions, proposing areas for future research studies and assisting in theoretical generalisation of this aspect of the policy process. The benefit of multiple case studies, as argued by Yin (2003), is its ability to be generalisable to theoretical propositions (analytic generalization) rather than to enumerate frequencies (statistical generalization).³⁵ This was facilitated by a multiple case study design, the cross-national nature of the study, and the fact that it was underpinned by a theoretical framework.

This exploratory case study research had three broad aims. Firstly, it sought to identify the organisational reforms inside each school to support science and mathematics reforms. Secondly, it sought to ascertain the perspectives of two key gate-keepers in the school-

based policy process, management and teachers. Thirdly, it classified the schools on the basis of the opportunities they provided for teachers to be professional learners. This presented one *snapshot in time* of the *mutual adaptation process* of reform implementation.³⁶ Case study research is well suited to an exploratory qualitative study in-situ and, as an eclectic research approach, had the most appropriate blend of features to render the school-based part of the study trustworthy. It followed the guidance of Crossley and Vulliamy (1984), Stenhouse (1979) and Stake (1995).³⁷⁻³⁹ Crossley and Vulliamy (1984) in a seminal paper dealing specifically with the use of case study research in comparative research identified some strengths and limitations of the comparative research method.⁴⁰ Among the strengths identified were:

- The method can give new insights and critical perspectives into the process of schooling.
- It may be used to present a diversity of perspectives.
- Focus on the process rather than on the terminal behaviour may detect desirable or undesirable side effects which may be significant to the change process.

Among the limitations of comparative case study research identified were:

- It deals in insights rather than generalisable laws as a basis for understanding.
- It may include researcher bias.
- It often lacks rigour in data collection.
- It often lacks a theoretical framework.

Crossley and Vulliamy (1984) focus on the potential of comparative case study research to improve policies and gain a deeper understanding of education systems:

The potential of (comparative case study research) within the field is considerable. Case study need not be purely descriptive; it need not be limited to the micro-level; and it need not ignore comparative analysis itself. By focusing upon the complexities of educational practice, it can lead to important modifications of both educational policies and comparative theories of educational systems.⁴¹

They suggest that combining macro and micro perspectives can give an increased awareness of the factors that influence the functioning of a change process:

Case studies can usefully contribute to the analysis of contemporary educational problems, how macro- and micro- level research can be profitably combined and how more general conclusions can be abstracted from such work.⁴²

Stake (1995) argued that case study research was both an art and a science and saw merit in the research study of a single case.⁴³ The study of a single case, for its own inherent qualities, had the potential to yield significant findings. He identified three main types of case study: *intrinsic* case study that sought to gain a deeper understanding on one particular case, *instrumental* case study involved examining a particular case to gain insight into a particular problem or issue and a *collective* case study which involved groups of individual studies to give a fuller picture.

Yin (1994), like Rust et al (1999), argued for a greater emphasis on the scientific aspect of the study to ensure improved quality control.^{44,45} Yin (1994) argued that the strength of case study research was its ability to give fine grain information from the actual site of the phenomenon. It's weakness was it's openness to the bias of the researcher and oftentimes lack of rigour and transparency. These weaknesses could be counteracted through using a more data driven and scientific approach. School generated numerical data in this study included data with respect to the number of science laboratories, the science and mathematics budgets, the formal time allocation for teachers to meet in school development planning and collaboration and the teacher profiles and qualifications. The study included 28 respondents in Ireland and 27 respondents in Norway. Two types of *embedded cases* were identified inside each school.⁴⁶ The first *embedded* case presented

the organizational features of each school in the study. The second *embedded case* presented the perspectives of the management and teachers. This data was then used to establish the extent to which each school could be regarded as *learning-enriched schools*, *learning impoverished schools* and *moderately-impoverished schools* based on criteria developed from Rosenholtz's (1991) study of the social organization of teacher learning (Table 2.1).⁴⁷

3.5.3.1 Selection of Country, Number and Type of Case Study Schools.

The selection process involved selection of a country as comparator with Ireland, selection of the case study schools and selection of the sample size. Norway was chosen as the comparator for a variety of reasons: it was one of the Nordic countries which at the start of the millennium were attracting international attention in the PISA-world of literacy. The Nordic countries were also noted internationally for their social-democratic policies and close attention to issues of equity. Furthermore Norway was similar to Ireland in population terms and this presented the unique possibility of comparable data. The aim of the study was to learn more about the policy process in Ireland through the lens of this cross-national comparative study and for this reason Ireland was chosen as the major domain and Norway as the minor domain. The researcher was positioned as an *insider* in Ireland and an *outsider* in Norway.

Purposive sampling was used in that the schools were chosen for their good reputation in science and mathematics education.⁴⁸ The five case study schools chosen in each country, in the northern and western regions, were recommended by teacher educators in both countries. They were not close to the capital cities, Dublin and Oslo, and the Ministries of Education, the DES or the MER, had no role in their selection. The case study schools in Ireland represented the full range of school types and included one private fee-paying school and one all Irish school. The Norwegian schools were all public-schools. Five

schools in each country were chosen as a sample size that could give a robust picture of the *mutual adaptation* process. This placed the study in the middle range (from five to thirty cases) and deemed it a small-N study.⁴⁹

3.5.3.2 Data Collection Methods

A number of methods of data collection were used including questionnaires, interviews, field-notes based on observations and a tour of the facilities. Each of these methods are now considered in turn.

Questionnaires

Ethical considerations as elaborated in Cohen, Manion and Morrison (2007) with regard to using questionnaires included the right of respondents to give their informed consent to the research, to withdraw that right at any stage and to have the guarantee of confidentiality and non-traceability.⁵⁰ An information sheet was sent to schools highlighting the aims of the research and thanking them for their co-operation in advance. The purpose of the questionnaire in this research study was to elicit information on process and organisation issues in science and mathematics reform. In addition a school profile and teacher profile section was included to give a richer description. Questionnaires for Norway were translated using the services of a professional translations agency to assist with answering of questions in Norway and to respect cultural diversity. Both English and Norwegian questionnaires were given to the respondents in Norway. The larger the sample size the greater the need for closed highly structured questions, mostly providing numerical data.⁵¹ This generally necessitates the pre-coding of questions which lengthens the process of preparing the questionnaire but considerably expedites the analysis process. The sample size in this research study was medium, typically thirty respondents in each country. A small number of open questions gave an opportunity to capture reality:

An open-ended question can catch the authenticity, richness, depth of response, honesty and candour which, as is argued elsewhere in this book, are the hallmarks of qualitative data.⁵²

A rating scale has the benefit of eliciting greater subtlety in the response while it also contains the problem of interpretation: one person's *strongly agree* might elicit an *agree* response from a different respondent.⁵³ During the early design stage of the questionnaires suggestions for improvement were sought from two external academic scholars, one in each country, before they were finally printed. Questionnaires were designed for both management and teachers. The subject teacher included physics, chemistry, biology and mathematics teachers based on one academic programme in upper secondary education in Ireland and Norway. In Ireland the teachers came from the *Leaving Certificate (established)* programme while in Norway the teachers came from the *Administration and General Studies* course of study. Questionnaires were also designed for members of the management team. In Ireland this included the Principal, Deputy Principal or Guidance Counsellor. In Norway the management team included the Head (*Rektor*), Deputy Head (*Assist. Rektor*), the Head of Department or the Guidance Counsellor. Samples of the questionnaires used, for both management and teachers in both countries, are given in Appendix XI to XV.

3.5.3.3 Semi-Structured Interviews

Semi-structured interviews aimed to give a thicker description to the questionnaire data and assist in ascertaining the extent of adaptation of the reforms in science and mathematics through the perspectives of teachers and management. The overall aim of the school-based research was to glean an accurate picture with regard to process and organisational issues firstly inside each school, as *embedded cases*, and secondly inside the five schools. Between five to six respondents inside each school were interviewed and between interview responses, field-notes and questionnaires it was possible to arrive at an accurate picture of the reform process in each school. The semi-structured interviews

proceeded using an approach suggested by Patton (1992) which ensured that while data collection was systematic the interviews remained fairly conversational and situational.⁵⁴ All interviews were recorded on audio tape and transcripts of these were then used as the data-source. Interviews in Norway were all conducted in English. Confidentiality was assured for respondents and schools were identified by pseudonyms. Sensitive information, such as teacher qualification or membership of a voluntary subject associations, was confined to the cross-case analysis part of the study in each country. This offered further protection and confidentiality to each respondent in the study.

3.5.3.4. Field-Notes

A tour of the school facilities in general, and particularly the science and mathematics facilities, was carried out and documented in the field-notes compiled immediately after each visit. The notes followed a semi-structured observation approach and a checklist, Table 3.1, was used to assist the documenting of field notes immediately after each visit.⁵⁵ Field-notes gave an overview of the school plant and facilities for both science and mathematics teachers. They noted the science, mathematics and teacher facilities, the availability of resources and budget allocations for science and mathematics. They also noted the availability of structures for *time-in-school* for science and mathematics teachers to meet for planning and development.

3.5.3.5 Comparative Data Analysis

Data analysis according to Miles and Huberman (1994) consists of data reduction, data display and conclusion drawing.⁵⁶ The final stream of activity is conclusion drawing and this involves noting regularities and patterns across the data as it is being assembled and re-worked:

The competent researcher holds these conclusions lightly, maintaining openness and scepticism, but the conclusions are still there, inchoate and vague at first, then increasingly explicit and grounded.⁵⁷

Table 3.1 Check-List of facilities and resources in school observations.

Area of School	Check-List of Facilities & Resources
General Facilities	What is the general condition of the plant? What structures are in place for teachers to meet, during the school-day, or to convene meetings with science and mathematics teachers? What facilities have science and mathematics teachers to pre-plan for class or to prepare for experiments or activity-based learning?
Science Facilities	How many science laboratories are there? What is the condition of the laboratories? What ICT facilities (internet, data logging equipment) are present in the laboratories? Is there a designated science budget? Who is responsible for the upkeep of the laboratories?
Mathematics Facilities	Is there a designated mathematics budget and who is responsible for this? Are there resources to support the teaching of mathematics? Are there ICT facilities for the teaching of mathematics?
Additional Resources	Are there any additional resources for the teaching of science or mathematics?

The coding of data in the data analysis stage of the research process arises from the theoretical framework for the study, the research questions and the hypothesis. Data analysis involves *examining, categorising, tabulating, testing or otherwise recombining both quantitative and qualitative evidence* to address the initial theoretical framework and the hypothesis of the study.⁵⁸ An analysis strategy helps to define priorities for what to analyse and why. The most preferred strategy in this study, as per the argument of Yin (2003), is to follow the theoretical framework that led to the case study.⁵⁹ These are reflected in the research questions and the theoretical framework and include the interweaving sub-themes of the study: changing pedagogy and assessment, organisational

structures and supports and teaching as a professional praxis. This helps to *focus attention on certain data and to ignore other data*.⁶⁰ In the analysis of a multiple case study, such as this one, there is the possibility of both single case and cross-case synthesis of findings.⁶¹

The findings in this study, were drawn through the theoretical framework, and supported by a small number of comparative *word-tables* that displayed the data.⁶² This approach to analysis allows one to probe deeper into the findings that emerge and leads the possibility of a number of fresh insights:

an important caveat in conducting cross-case synthesis is that the examination of word tables for cross-case patterns will rely strongly on argumentative interpretation, not numeric tallies.⁶³

Yin (2003) identifies essential criteria for high quality analysis including: all evidence is attended to, the analysis addresses the most significant aspect of the study and the researcher makes full use of their own prior expert knowledge.⁶⁴ Data analysis in this study took place after the data was collected and interviews were transcribed. The data analysis process involved interpreting and making sense of data using the theoretical framework. There were quite a number of steps taken in the data analysis process. Firstly the quantitative findings were tabulated for each school and later for multiples cases in each country. Secondary coding was used with the narrative data as it was investigated for mention of the three sub-themes: pedagogy and assessment (PED), organisational structures and supports (ORG) and finally teaching as a professional praxis (PRAX). This was cross-checked with the data generated by the questionnaires and field-notes. An initial case study draft report was then written for each school and an aggregate report for each country and checked with my supervisor. Several iterations of this process were repeated giving a far more detailed sifting of the data.

The overall school based interpretation and the tables of data from each school were rechecked with each school and some minor adjustments made as a result. A number of cross-checks for improving the validity and reliability of findings were taken in the research design phase, the data collection phase and the data analysis phase. These are dealt with in Section 3.6. Finally the depth and richness of the case study was only completely achieved through the search for a rival explanation. This helped give a more detailed sifting of the data and brought out a more robust landscape for each case study. To improve the rigour of the data analysis the final distillation of findings was achieved through a counting process that ascertained the number of teachers in the study who were self-reporting that they were (a) deeply sceptical of the reforms (b) contesting the reforms (c) neutral about the reforms or were (d) adapting the reforms. Evidence from the case study research, in each country, was then compared with the evidence emerging from the official document search and the literature. This final comparative analysis of findings generated a number of final conclusions and some recommendations (Chapter 8).

3.6 Validity and Reliability of Data Collection and Data Analysis Methods

Making a claim to knowledge requires that data collection methods and data analysis approaches are all conducted following a number of research protocols, that the canons and principles of research are fully applied and are subjected to a range of tests so that the reliability and validity of findings may be assured. A range of methods and tests are suggested in the literature to assure the rigour and accuracy of qualitative research findings. Several of these tests and methods have been used in this study. To ensure reliability and validity of findings from the official document search and the case study research *time-honoured procedures, such as triangulation*, were used to enhance the credibility of inferences.⁶⁵ A number of different cross-checks were used including *triangulation of methods* in the overall research design (official document search, case

study research, literature review and reflexive and reflective study) and a *triangulation of data capture methods* inside each school (questionnaires, interviews, tour of plant and field-notes from observations).

In the document analysis part of the study it involved checking and cross-checking sources and statistical data for accuracy. In the case study schools it involved fully informing respondents about the study, ensuring that all respondents know that they had a right to withdraw from the study at any time and assuring respondent confidentiality. The process began with a letter to schools informing them about the nature of the research. This letter was written in consultation with my supervisor (Appendix I). To fully support the quality of the research findings, the reliability and validity of the research data from this study, the researcher considers the concept of triangulation as it applies to qualitative research, the range of tests for validating the qualitative data, by Smith (1996) and Yin (2003).^{66,67} Neither believing in unbridled subjectivity nor absolute relativism, this researcher sought to reduce researcher bias through a reflexive and reflective process. In this way the researcher adopted a neutral non-judgmental stance to the data as it emerged, with no agenda other than to seek a deeper understanding of the phenomenon under study. These three aspects of quality assurance - triangulation, validity tests and conducting a reflexive and reflective study - are now considered in greater detail.

3.6.1 Triangulation in Qualitative Research

Triangulation, using more than one research method to gather data, may help reduce the likelihood of misinterpretation. Cross-checks of both the data generated and interpretations of the data are required. It is defined as a multi-method approach, by Cohen, Manion and Morrison (2007), it helps reduce bias and give greater confidence in findings and generate greater trustworthiness in the research study.⁶⁸ Ensuring the

trustworthiness of the research findings is, however, much more complex than simply relying on a multi-method approach. This alone does not necessarily guarantee the trustworthiness of findings in a simplistic additive way:

A simplistic view of triangulation does without doubt run the risk of being accused of naïve realism. It also supports the unhelpful notion that using multiple methods will lead to sounder, consensual conclusions in an easy, additive fashion.⁶⁹

In qualitative research triangulation may be perceived as a process of seeking multiple perspectives. This is achieved in this research study through using a range of lenses to view the data emerging. In this research it included the perspectives of the researcher, the theoretical framework for the study, the official policy documents and the perspectives of both teachers and management inside the case study schools:

Triangulation ...facilitates interpretation by offering views of the data through different explanatory lenses.⁷⁰

3.6.2 Validating Qualitative Data.

According to Cohen, Manion and Morrison (2007) validation is different for qualitative and quantitative studies:

In qualitative data validity might be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher. In quantitative data validity might be improved through careful sampling, appropriate instrumentation and appropriate statistical treatments of the data. It is impossible for research to be 100 per cent valid; that is the optimism of perfection.⁷¹

Validity is achieved through a number of different ways including reducing researcher bias through a reflexive and reflective self-evaluation and fully capturing the *boundedness* of the cases and the overall limitations of the entire study. Smith (1996) presents five criteria for validating qualitative data.⁷² These criteria include *internal coherence*, *presentation of evidence*, *independent audit*, *triangulation* and *member validation*.⁷³ Each of these is dealt with in turn and the extent to which this research study used the criterion is indicated. *Internal coherence* considers the coherence of the argument being made and

the extent to which contradictions and other ways of interpreting the data are dealt with. This criterion was used, after consultation with my supervisor, to revisit the data emerging from the case study schools to search for rival explanations. It assisted in questioning the self-reported traditional stance of respondents, was further enhanced by a counting process that quantified the level of contestation of the reforms, and helped present a more robust and rigorous picture of the case study findings.

Presentation of evidence concerned itself with ensuring that the research report had sufficient raw data so that the reader could interrogate the interpretation being made. Initially, in this study, case study findings were presented as an aggregate case report. Through the advice of my supervisor this was changed and raw data from each case study school was presented in addition to the cross-case synthesis. This ensured that sufficient raw data was presented so that the reader was free to interrogate any interpretation made. *Independent audit* concerned itself with giving the file of material to an independent researcher and ensuring that a logical progression and coherent chain of arguments runs through from the initial data to the final write-up. This independent audit, in this case study, was conducted in two ways. Firstly my supervisor cross checked the raw data and the initial drafts of the case report and later version of the aggregate case report. In addition to this one teacher educator in each country, Ireland and Norway, reviewed my initial draft of the case report. From comments received minor adjustments were made.

Triangulation, as dealt with earlier in this section, is a way of getting a richer and fuller story. It represents a way of capturing *multiple voices* and *multiple truths* that exist in relation to the phenomenon under study. The multiple perspectives in this study included the *voices* of the policymakers, through *policy as text* over an extended time-frame, the *voices* of management, the *voices* of teachers and the *voice* of the researcher. *Member*

validation concerned itself with bringing back to the respondents an analysis of the responses to enable them to comment on the interpretation. This was conducted in this research study for one aspect. It involved the return to the school of the overall initial interpretation of the school. This interpretation was validated by each school, with the exception of one case study school in Norway, where a minor adjustment needed to be made as a result of this process.

Further tests for validation of empirical social research, including case study research, are put forward by Yin (2003).⁷⁴ He uses the four tests of *construct validity*, *internal validity*, *external validity* and *reliability* to assure the reliability and validity of research findings.⁷⁵ *Construct validity* is concerned that correct operational procedures and occurs at the data collection stage. It is increased by using multiple sources of data, establishing a chain of evidence and having a draft case study report reviewed by key informants. In this study multiple data sources were used (questionnaires, interviews, field-notes), a chain of evidence was established and a number of informants reviewed the draft case study report. *Internal validity* comes into play during the data analysis stage. It concerns itself with taking rival explanations into account. The search for rival explanations, coupled with quantifying the level of contestation found in the chain of evidence emerging, yielded a broader canvas and presented a more robust and rigorous landscape than was found from initial readings of the data. Rival explanations involved questioning the chain of evidence as it was beginning to follow a replication logic. It meant questioning the self-reported claims by the teachers that they were traditional and proactively seeking evidence to contradict their claims. It meant questioning the policy reforms and their insistence that teachers could create an empowering and independent learning culture in schools while also assisting students to gain access to higher education.

External validity is concerned with the initial research design and the problem of knowing whether the study's findings are generalisable. External validity is assisted by having a theoretical framework underpinning the study. In this study a novel conceptual framework was devised for the study and qualitative evidence was found which supported theoretical generalisation.

Reliability ensures that if the same study were conducted by another researcher, in a similar context and time-frame then the same results would be found. This deems that the research would be repeatable. For the study to be reliable the researcher needs to reduce possible sources of error and biases in the study. The study needs to map out steps taken so that another researcher could repeat the procedures and arrive at the same results. This includes the research questions driving the study, the theoretical framework used, the data collection and data analysis procedures for arriving at the case study report.⁷⁶ The approach taken in this study to reduce researcher bias is now considered.

3.6.3 Reflexive and Reflective Study

Neither believing in unbridled subjectivity nor absolute relativism, this researcher sought to reduce researcher bias and to make personal theories explicit through a reflexive and reflective process. The unpacking and deconstructing of the personal theories and biases of the researcher is an essential process to improve the reliability of findings. The process allows for the development of a subjective objectivity:

Being objective in our sense means working toward unbiased statements through the procedures of the discipline, observing the canons of proper argument and methodology, maintaining a healthy scepticism, and being vigilant to eradicate sources of bias.⁷⁷

It is necessary for the researcher to be open to the data as it emerges:

Complete objectivity is impossible; pure subjectivity undermines credibility; the researcher's passion is understanding the world in all its complexity – not proving something, not advocating, not advancing personal agendas, but understanding; the researcher includes personal; experience and empathic insight as part of the relevant data, while taking a neutral non-judgmental stance towards whatever content may emerge.⁷⁸

This reflective approach helps to develop the type of *empathic neutrality* that the case study researcher requires in their field work. A final personal reflection positioning this researcher reflexively and reflectively is found in Appendix II.

3.7 Ethical Guidelines

Research studies need to be conducted in ways that are ethically sound and cause no harm to respondents. The research community is supported in behaving in ethical ways through access to professional association guidelines and codes of research practice. For example, the *British Education Research Association* (BERA) publishes ethical guidelines for researchers advising how to conduct educational research in ways that are not potentially harmful to respondents.⁷⁹ The ethical codes of research practice involve making all participants in the study fully aware what the research is about, giving an opportunity to respondents to be fully informed, to be involved voluntarily and to know of their right to withdraw at any stage. It also involves balancing the public's right to know with respect for the privacy of each respondent.⁸⁰ Robinson-Pant (2005) highlights a number of distinctive ethical issues facing comparative researchers working in cross-national comparative studies and using cross-cultural perspectives.⁸¹ Ethical issues of this type have both moral and legal dimensions. For example, the sensitivity and sensibility required of the *outside researcher* given their lack of familiarity in local practices, beliefs and values. Individuals and cultures do not share the same sensitivities and researchers need to be aware of this lest superficial readings are drawn from the findings.⁸²

3.8 Limitations of the Research Study

The research study was bounded by time and by research topic. This cross-national comparative study was designed to gather data from two distinct sources: the official policy documents related to science and mathematics and the case study findings, five in each country. The cross-national nature of the study gave the added advantage of the broader perspective and the opportunity to raise critical questions and extend theory. It had the disadvantage that the researcher was in continual struggle with *insider/outsider* roles and was constrained from generating interpretations from the differences found between different nations. Another limitation was that while the official policy text analysis was extensive and conducted over a forty five year time-frame the case study research was confined to one snap-shot in time, 2003-2004, and only identified the organizational reforms made and the perspectives of key policy-gatekeepers, management and teachers. The macro study did not explore *policy as influence* and seek the national policymakers' perspectives while the micro study did not seek the perspectives of other significant actors such as students, parents or guardians. The case study research only focused on the perspectives of day-to-day management team and teachers. While the study enquired into practical items it did not delve deeper into the quality of interaction within the school culture. For example, while it sought to ascertain the extent of time-in-school set aside for science and mathematics teachers to meet and plan collectively it did not enquire into the agenda items for these meetings, the extent of dialogue with respect to teaching and learning or the quality of these interactions.

3.9 Chapter Three: Summary

Chapter Three presents the research literature review undertaken for this study and how the research questions led to the research design and plan. It considers the rationale for the research, the ontological values of the researcher, the researcher's view of the

epistemology of knowledge, the research methodology chosen and the great care taken in following the canons and principles of research to ensure that the study was ethically sound and the data generated was reliable and valid. This research is a study of a particular aspect of the education policy process – the point at which the rhetoric of the policy documents meets the reality of praxis, through the perspectives of management and teachers. The subjects under study were science and mathematics in the academic pathway of upper secondary education. This piece of research was chosen because of the national policy interest in improving uptake in the physical sciences and mathematics, international interest in improving science and mathematics literacy among young people and personal interest in the policy process through past professional experiences (Appendix II).

This researcher aligned herself with the majority of comparative researchers who, as argued by Rust et al (1999), tend to see reality as somewhat subjective and multiple rather than objective and singular.⁸³ Epistemologically these researchers would tend to interact with that being researched and would tend to not see research as being completely value-free and unbiased. Neither believing in unbridled subjectivity nor absolute relativism, while positioning herself along the qualitative-quantitative continuum, this researcher sought to reduce researcher bias through a reflexive and reflective process. Being objective meant observing the canons of proper argument and methodology and maintaining a healthy scepticism. The aim of the study was to gain a deeper understanding of this important aspect of the complex social phenomenon that is the policy process. This involved taking a neutral non-judgmental stance toward whatever emerges from the study. This research was conceptualised as a cross-national comparative research study, between Ireland and Norway, drawing on a forty five year timeframe to present the macro landscape and using an exploratory multiple case study design, in each country, to present the micro landscape. This research design used a mixed methods approach, as argued by

Tashakkorri and Teddlie (1998, 2003).^{84,85} This mostly used an interpretive paradigm but was supplemented by a small and significant quantitative study. The cross-national aspect of the study presented a broader perspective and gave the added opportunity for theory generalisation, as argued by Eisenhardt (2002).⁸⁶

Official policy documents were interpreted using the argument of Wellington (2000).⁸⁷

Conducting cross-national case study research was guided by the canons and principals of, among others, Crossley and Vulliamy (1984).⁸⁸ Purposive sampling was used and schools were selected by teacher educators in both countries and not the Ministries of Education.

The study was a small-N study, having ten cases study schools in total. Case study research was chosen because of its eclectic flexibility and the need to place the respondents, twenty eight in Ireland and twenty seven in Norway, within their socio-cultural context, within their school organisational structures and supports and within the multiple perspectives of management and teachers in the same physical environment. This added the possibility of congruence or dissonance between the voices of management and teachers and/or their physical environment and may further illuminate the process. Data collection methods included questionnaires, interviews and field-notes. Data analysis followed a process of coding, pattern-matching, tabulation and eventually searching for rival explanations. A total of nine validity tests of Smith (1996) and Yin (2003) guided the search for validity and reliability of the research design, data collection and data analysis phases of this study.^{89,90} These tests included using a range of lenses to triangulate multiple perspectives, having a theoretical framework, using multiple sources of evidence, cross-checking data with respondents and schools, having key informants review drafts of the case report, pattern-building and searching for rival explanations.

A number of ethical guidelines underpinned this study including the respondents' right to fully informed consent and their right to withdraw at any point during the study. It also

included the moral obligation to ensure confidentiality for respondents while at the same time achieving a balance of what needed to be told. Great care and consideration was taken with regard to each of these and a number of decisions were taken, for example, to use pseudonyms for the schools and to place sensitive data such as teacher qualifications in an aggregate table in the cross-case synthesis for each country.

The limitations of the research study included the missing voices of additional key actors in the policy process, such as, policymakers, students and parents. This case study research was exploratory and while it was able to give a snap-shot in time of the perspective of management and teachers it also raised critical questions concerning, for example, the quality of teacher meetings in the development of a culture of evaluation, that needed further longitudinal and larger-scale research for fuller illumination.

Chapter Four: *Policy as Text* in Upper Secondary Science and Mathematics in the Republic of Ireland from 1960 to 2005

Chapter Four presents findings from the official policy document search in the Republic of Ireland in the time-frame 1960-2005. The chapter considers: background and context, the macro policy process, the micro policy process, curricular reforms in senior cycle (upper secondary) science and mathematics in terms of pedagogy and assessment and teacher reforms. In addition to the official syllabuses for science and mathematics and related teacher guidelines the archive search included a forty five year search of the *Dáil Eireann* Reports and the newsletters, reports and journals of the ISTA, IMTA and NCCA. The summary reconsiders the findings by reflecting and refracting them through the five research questions driving the study and the theoretical framework for the study.

4.1 Background and Context

The Republic of Ireland, on the westernmost edge of Europe, had in the 2002 Census a population of 3,917,200 million people of which 5.8 % or 227,198 were non-Irish nationals (Appendix III).^{1,2} The country had turned full-circle from a brief period of economic prosperity in the nineteen sixties economic depression and national stringency in the nineteen seventies, eighties and early nineties to an economic boom, termed the *Celtic Tiger* economy, that continued from the late nineties until the end of this research study. The majority of the population are Catholic with religion playing a dominant role in the shaping of the public education system.³ The education system is described as a state-aided system with the state providing the majority of funding for schools which are mostly privately owned and denominational.⁴

The curriculum is prescribed by the state and the state administers a national public examination system for all students in all subjects at the end of both lower and upper

secondary education. The number of students graduating in the final *Leaving Certificate* examination, at the end of upper secondary education, increased seven fold in the period under study (Figure 4.1).⁵ This exponential growth was matched by a corresponding increase in the number of second-level teachers.⁶ The number of students completing upper secondary education by 2004 was 85.3%, higher than the EU average of 76.7%.⁷

It is the science and mathematics subjects in this academic programme that is the focus of this exploratory study. Uptake of the physical sciences showed a declining pattern from the mid nineteen nineties onwards and this became a source of national concern by the early years of this century. The preamble to all senior cycle science syllabuses indicated just how important this issue was seen at government level:

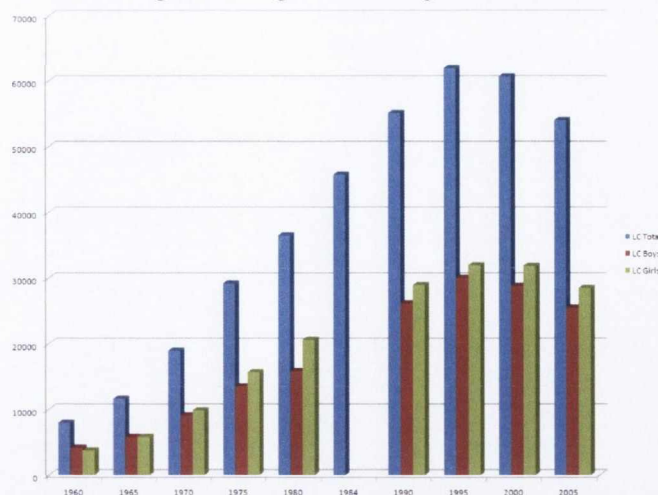
Science education in senior cycle should reflect the changing needs of students and the growing significance of science for strategic development in Ireland.⁸

Concern at the declining uptake in the physical sciences and mathematics was expressed at the level of the Ministry of Education and Science. It is to this macro policy process that we now turn.

4.2 Macro Policy Process

Education policy was formulated through a combination of policymakers in dialogue with Department of Education officials with final sole responsibility resting with the Minister for Education.⁹ Policy making in education in Ireland can be better understood by an exploration of church-state relations which is outside the scope of this thesis. It was during the nineteen sixties, with the publication of the first OECD study, that the government first strongly asserted itself as a policymaker in education. The first strong public expression of this occurred in 1963 with a policy speech by Minister Patrick Hillery T.D.¹⁰ This new found confidence continued apace from that time onwards with many Ministers leaving their stamp on the education system through new initiatives and policy changes.

Figure 4.1 Number of students graduating in Leaving Certificate examination 1960-2005.



Source: Compiled by Author from *Statistical Reports*, 1960-2004, Department of Education and Science and State Examination Commission *Annual Report*, 2005.

The need for a better foundation in mathematics and science was recognised in the OECD *Country Review of Ireland* 1969.¹¹ The lack of qualified science and mathematics teachers featured in the background study to the review, the *Investment in Education Report*, 1967.¹² The team noted that there were few students studying science and few teachers with the necessary specialist qualifications:

Pupils devoted about 10% of their time to the physical sciences and biology and 50% to the classics. The Irish delegation pointed out that this state of affairs could not be righted without a substantial injection of additional financial resources into secondary education. For instance, the development of science teaching necessitated expenditure on the installation and fitting out of laboratories which most secondary schools were at present quite unable to consider, even with the assistance they received from the state for this purpose.¹³

Various Ministers for Education used their position to bring about reforms in the system (Appendix IV).¹⁴ At the level of senior cycle, in the 1960-2005 timeframe, three Ministers for Education introduced changes that were to increase the number of students and offer a more comprehensive pathway of options. Minister Donagh O'Malley T.D. introduced a free education and transport scheme in 1967 which opened up universal access to the school system.¹⁵ Minister Niamh Bhreathnach T.D. restructured senior cycle in 1995, providing a pathway of options for pupils in post-16 non-compulsory education.¹⁶

From the late nineteen nineties a series of events changed the shape of senior cycle science education. A national survey of science facilities was conducted by the DES during 1998-99 to determine the state of science infrastructure within second level schools.¹⁷ Findings indicated that the vast majority of schools did not use ICT facilities and there was a need to upgrade school laboratories. Minister Michael Woods T.D. sanctioned the payment of a grant of £2,500 to schools to purchase a personal computer and printer and £1,500 for the purchase of laboratory equipment.^{18,19} This was the beginning of a period of national investment in the sciences, in the form of once-off grants, for a variety of specified purposes. In October 2000 Minister Woods T.D. established a forty four person national task force on the physical sciences to research the decline in uptake at second level.²⁰ Their report, *The Task Force Report on the Physical Sciences Results and Recommendations*, was published in March 2002.²¹ Curriculum reforms at senior cycle was initiated and grants to upgrade laboratories were increased to Euro 3,500 per laboratory: in total over Euro 16 million was made available to upgrade laboratories.²² Senior cycle reform focused on teaching the subjects experimentally:

As well as the addition of new, up-to-date content, these syllabi have an increased emphasis on student practical work and on the interface between science, technology and society. These changes are intended to highlight for pupils the relevance of these subjects to their everyday lives.²³

A capital grants programme for senior cycle science was introduced with a Euro 10 per capita grant per students choosing the physical sciences.^{24,25} The grading of senior cycle science subjects came under scrutiny and efforts were made to redress imbalances.²⁶ Data-logging grants were approved for all post-primary schools.²⁷ The report recommended an action plan based on improving planning, resources, teaching, learning and assessment.²⁸ The plan was estimated at Euro 177.7 million in capital expenditure and Euro 66 million in recurring costs.²⁹ This included a Euro 30 million capital expenditure to improve infrastructure; Euro 2.5 million to improve teaching and learning and Euro 7.2 million to

help schools plan for science. However, the government resisted implementing the report in its entirety as recommended.^{30,31}

Contemporaneous with these developments the DES was undergoing a major review of its own internal operations and staffing needs.³² The *Cromien Report*, published in October 2000, highlighted the serious administrative burden and the lack of capacity among the inspectorate to become involved in quality assurance and policy making:

Because of day to day pressures in sections not enough time is given to standing back from the work and assessing where the Department of Education and Science is going and what are its medium-term plans for education. This is particularly serious because of the urgent need for thinking about what is called for shorthand the school of the future, namely, changes both in the nature of educational provision and in educational practice coming as a result of the rapidly developing world of new technologies.³³

Several functions of the DES were outsourced as part of a reorganisation. State examinations were outsourced to a new statutory body, the *State Examinations Commission* (SEC) from 2003.³⁴ From 1985 onwards, syllabus changes were introduced by way of NCCA course committees using a consultation process including representation from inspectors, subject associations, management bodies, teachers' unions and third level education institutions.^{35,36}

Education policy-making followed a corporatist model of consensus-making with the education partners. The nineteen nineties proved to be the decade with the highest level of consultation among stakeholders and led to the publication of a rich variety of national education reports (Table 4.1). This was followed by a raft of legislation concerning education (Table 4.2). The DES introduced a new system of inspection and quality assurance to schools and it is to this system that we now turn.

4.2.1 Inspection System

From 1960 to the 1990s privately owned secondary schools did not take kindly to inspection officials regarding them for the most part as interference:

The sensitivity surrounding church/state relations in the education system is clearly evident in the question of the mainly church-controlled secondary or intermediate schools. The absence of an inspectorate from 1878 to 1902 is a measure of that sensitivity, deriving directly from the failure of the Intermediate Education Act of 1878 to specify any criteria as to school buildings, teacher qualifications, school organisation;....By the time the inspection process was introduced in 1902 by the appointment of temporary English inspectors, opposition to any inspection of the private state-funded schools had grown significantly.³⁷

Table 4.1 National reports that influenced senior cycle policy changes 1990-2005.
Sources: *indicated*.

Year	Title of Report
1991	<i>Senior Cycle, Structure, Format and Programmes</i> , April 1991, Dublin: National Council for Curriculum and Assessment.
1992	Department of Education <i>Education for A Changing World Green Paper Ireland</i> , 1992 Dublin: The Stationery Office.
1994	<i>Report on the National Education Convention</i> , 1994, Dublin: The National Education Convention Secretariat.
1995	Department of Education, <i>Charting our Education Future White Paper on Education</i> 1995 Dublin: The Stationery Office.
1998	Government of Ireland 1998 <i>Commission on the Points System</i> Consultative Process – Background Document Dublin: Stationery Office.
2005	<i>Proposals for the Future Development of Senior Cycle Education in Ireland</i> April 2005, Dublin: National Council for Curriculum and Assessment.

Table 4.2 Education legislation enacted from 1998 – 2005.

Year	Title of the Act
1998	Education Act
1999	Qualifications (Education and Training) Act
2000	Education (Welfare) Act
2001	Vocational Education (Amendment) Act
2001	Teaching Council Act
2003	Education for Persons with Disabilities

The Department issued a number of circular letters obliging pupils to present experimental copies for inspection in the physical sciences.³⁸⁻⁴⁰ Childs (1983) noted the difficulty of having this type of inspection in chemistry given that there were only two or three inspectors in the system at the time.⁴¹ The DES started a partnership model of inspection where its external role of inspection was to compliment and supplement an internal system of review that involved the school as a proactive agent of change in planning and evaluation of its own destiny. This role was copper-fastened in the Education Act under

Section 13 (3) (b).⁴² The DES first introduced a pilot study in 1998/99 and based on these findings it introduced whole school evaluation nationally in 2003.^{43,44} The new system, *Looking at Our Schools* (LAOS) aimed to promote self-evaluation.

the inspectorate promoted self-evaluation and action planning for change and advised schools on ways in which available supports and expertise could be used to build upon existing strengths and to effectively address gaps in the quality of provision for pupils.⁴⁵

The evaluation framework used in LAOS 2003 evaluated schools on the basis of a number of factors, including quality of teaching and learning taking local contextual factors of schools into account (Table 4.3 and Table 4.4).

The Chief Inspectors Report 2005 indicated there were one hundred science inspections and fifty inspections in upper secondary mathematics over a three year time-frame.⁴⁶ The number of inspections, both individual subject inspections and whole school evaluations (WSE), began to increase from 2003 onwards (Table 4.5). Three circular letter were issued to inform schools of policy changes with regard to this process.⁴⁷⁻⁴⁹ However initial research findings from O'Hara and McNamara (2006) indicated that schools in Ireland had a poor track record in critical review and were not generally favourably disposed toward gathering evidence for self-improvement.⁵⁰

Table 4.3 Local contextual factors impacting on schools.

Number	Contextual Factors
1.	Size, location and catchment area of school
2.	Socio-economic circumstances of the students and the community
3.	Student special needs
4.	Physical, material and human resources available to the school
5.	Local employment availability and patterns

Source: Source: Department of Education and Science (2000) *Whole School Evaluation – WSE Draft Criteria for the Evaluation of Schools*, Dublin: DES.

Table 4.4 Some evaluation criteria used in LAOS 2003 and relevant to this study.

Area	Component	Optimal Level
Quality of School Management	Management Of Staff	In-school management actively fosters a partnership approach with staff in agreeing on and achieving the aims of the school. All staff members are encouraged and facilitated to take professional development courses.
	Management Of Resources	Resources are of high quality, well maintained and suitable to the needs of the school.
	Self-Review Self-Evaluation	A culture of self-review and improvement is evident in the work of in-school management.
Quality of Learning and Teaching	Methodology	Appropriate teaching strategies and methodologies are selected and employed with due regard for the range of student abilities, needs and interests. Teaching strategies and methodologies are varied and efficiently, effectively and creatively used in the implementation of the teaching programme.
Assessment Modes and Outcomes	A range of assessment modes are used to assess student competence and progress.	

Source: Department of Education and Science (2000) *Whole School Evaluation – WSE Draft Criteria for the Evaluation of Schools*, Inspectorate: Evaluation Support & Research Unit.

Table 4.5 Number of post-primary inspections between 2003-2005.

Year	2003	2004	2005
WSE	None	12	53
Subject Inspections	389	336	676

4.3 Micro Policy Process

The post-primary school progressed from being a publicly aided institution, with private management and ownership, in the nineteen sixties, to being regarded as the organic unit of educational change by 2005. The changes ranged from religious to lay management,

from strict division of responsibilities to whole school planning and development, from ad-hoc rules to legally binding, publicly accountable school policies and plans. The changes were not without difficulty and tensions and many barriers to structural change still remained by 2005. This section considers the school as the recognised site of policy implementation and views it from two different perspectives: the number and type of schools and the changing structure of management within the organisation.

4.3.1 Number and Type of Schools

The post-primary school system in the 1960s consisted of a bi-partite education system with secondary, secondary tops and vocational schools offering either an academic liberal curriculum or a work oriented vocational curriculum. In 1959/60 there were 510 secondary schools with 3,200 teachers in total of which 2,000 were religious and 1,200 were lay teachers.^{51,52} In 1964 the state announced the launch of a new type of school, the comprehensive school.⁵³ In the early nineteen seventies a newer version of the comprehensive school, the community school, was introduced. From 1970-2005 schools were classified as voluntary secondary schools, vocational schools, community schools, comprehensive schools and private fee-paying schools (Table 4.6).⁵⁴ More all-Irish medium post-primary schools were evolving in the non-Gaeltacht (non Irish-speaking) regions, called *Gaelscoileanna*.⁵⁵ Private fee-paying boarding schools, owned mostly by Church bodies, were also increasing in number. A newer type of private school promoting itself solely on the basis of excellence in examinations, disparagingly referred to as *grind schools*, was also taking a small but significant niche of the market.⁵⁶ In the early years of this century the state began to build a small number of well resourced *public-private-partnership* post-primary schools.⁵⁷

Table 4.6 Number and classification of post-primary schools 1970-2004.

Year Ending	Secondary Schools	Vocational / Community Colleges	Comprehensive Schools	Community Schools	Secondary Tops	Total
1975	540	249	14	16	12	831
1980	527	246	15	30	5	823
1985	507	247	15	43	2	814
1990	491	252	16	47	2	808
1995	452	247	16	60	-	775
2000	424	245	16	67	-	752
2004	406	247	16	74	-	743

4.3.2 Management of Schools

Among the functions of the Principal in Section V, Part 23 (2) (c) in the Education Act, 1998 is the requirement to promote teacher professional development:

be responsible for the creation...of a school environment which is supportive of learning among the students and which promotes the professional development of the teachers.⁵⁸

In the 1960s the academic secondary schools were managed by a Principal or Headmaster who, at the time, was usually the school owner or a member of the religious order owning the school. During the 1970s to 1990s post-primary schools moved from being managed by a single manager, answerable in most cases to the legal owners, the Trustees, to being run by a *Board of Management* (BOM) with representation from teachers, parents and the wider community. This was not without controversy, relating as it did to issues of power and control.⁵⁹ The management team of principal and deputy principal were assisted by a number of staff, A-post and B-post holders.⁶⁰ The appointment of teachers to these posts of responsibility was based on seniority. In 1998 a new middle management system was introduced. The Principal and Deputy Principal were now assisted by Assistant Principals and Special Duties Teachers.⁶¹ It was left to each school to decide how to allocate time:

The Departments of Education and Science and Finance accepted that the development of an effective in-school management system could require the allocation of time for duties. On that basis it was proposed that in regard to Assistant Principals, where possible, schools may allocate time for the performance of duties from existing resources.⁶²

School owners jealously guarded their right to manage their schools and resisted being told how to allocate time. This is best exemplified by the furore caused by the publication of a circular letter, *Time In School* 1995, detailing the minimum number of teaching days per year and allocating an additional six days for development planning.⁶³ The circular letter from the Ministry generated such controversy that it had to be quickly withdrawn. From 1999 onwards a support service to develop school planning was initiated by the *School Development Planning Initiative* (SDPI). However, the agenda for these meetings, in the early years of this century, did not rate *teaching and learning* or *reflective practice* as priority areas.⁶⁴

Research into the typical working day of the management team, by Leader and Boldt (1992), showed that interventionist crisis management and administration absorbed the full school day leaving little time for proactive educational leadership.⁶⁵ McManamly's (2002) research with school principals showed that teachers meeting teachers to discuss teaching and learning, either through school-based initiatives or inservice courses in the region, was considered by principals as something for outside of the school day:

Both in-school and out-of-school inservice erode teacher time and impact negatively on the day-to-day management of schools...principals conclude that inservice should be held out of school time ...(with) remuneration for attendingand a formal accreditation system should be put in place.⁶⁶

Sugrue (2002) identified this as an issue to be resolved if professional learning opportunities for teachers were to flourish:

If there is almost no time available during school hours for collaborative inquiry, not to mention ongoing professional learning, then the issue of time as a concern needs to be addressed as a major structural issue that currently is inhibiting both professional learning and school reform.⁶⁷

4.4 Curriculum Reform in Senior Cycle Education

From 1960-2005 senior cycle changed from a two year academic curriculum with restricted access, and participation rates of 18%, to a two year or three year experience with over 80% completion rates. When the map of senior cycle in 1963 is compared with

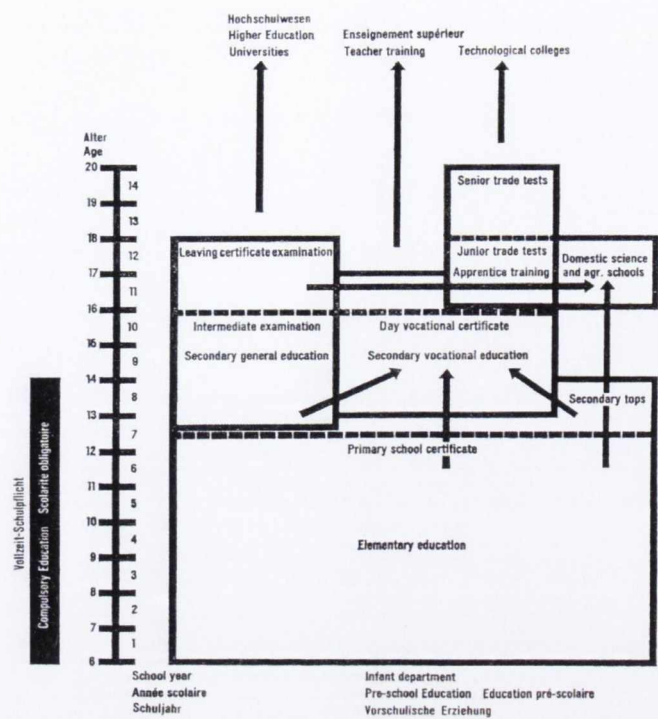
the map in 2005 the system shows that earlier divisions between separate academic and vocational pathways were reduced (Figure 4.2 and Figure 4.3). During the period 1960 to 1973 senior cycle academic education consisted of a two-year course of study culminating in an externally marked written examination, the *Leaving Certificate*, administered by the state. Typically five subjects were presented in the examination, with Irish having compulsory status.⁶⁸ Senior cycle was modified in 1974 to include an additional one year gap year experience, the Transition Year Option (TYO) programme, introduced on a pilot basis.⁶⁹ A number of optional pre-employment pathways were also offered on a pilot basis.^{70,71} However, the academically focused *Leaving Certificate* remained the main pathway through senior cycle for the vast majority of students, it retained its high status and was the gateway to university courses.

Consultations on reform of senior cycle took place over a nine year period, from 1985 to 1994.⁷²⁻⁷⁴ The *Curriculum Examinations Board* (later renamed the NCCA) took the view that the *Leaving Certificate* was not to be changed in any fundamental way:

The Leaving Certificate programme will continue to cater for the majority of senior cycle students in schools. The programme should therefore be adapted to cater for the increasingly diverse needs of students.⁷⁵

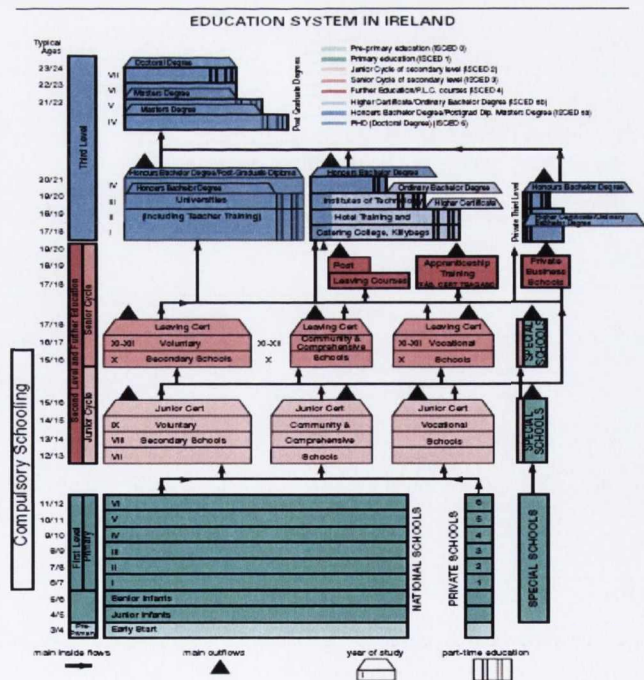
By 1984 the percentage taking *Leaving Certificate* had increased to 66% and, by 1988-1989, the number taking vocational programmes had increased.⁷⁶ The NCCA proposed a number of changes including a preferred model and a dual track model. In the preferred model there was flexibility between programmes, with students having a number of options. The second model had a ring-fenced separate vocational track. In May 1994 the Minister for Education, Niamh Bhreathnach T.D., restructured senior cycle.⁷⁷ The announcement was made through publicity material, brochure and video, and circular letters to schools.⁷⁸⁻⁸³

Figure 4.2 The Irish Education System in 1963.



Source: *Schools in Europe*, Edited by Walter Schultze on behalf of the German Institute for International Educational Research in co-operation with the Council for Cultural Co-operation of the Council of Europe, 61.

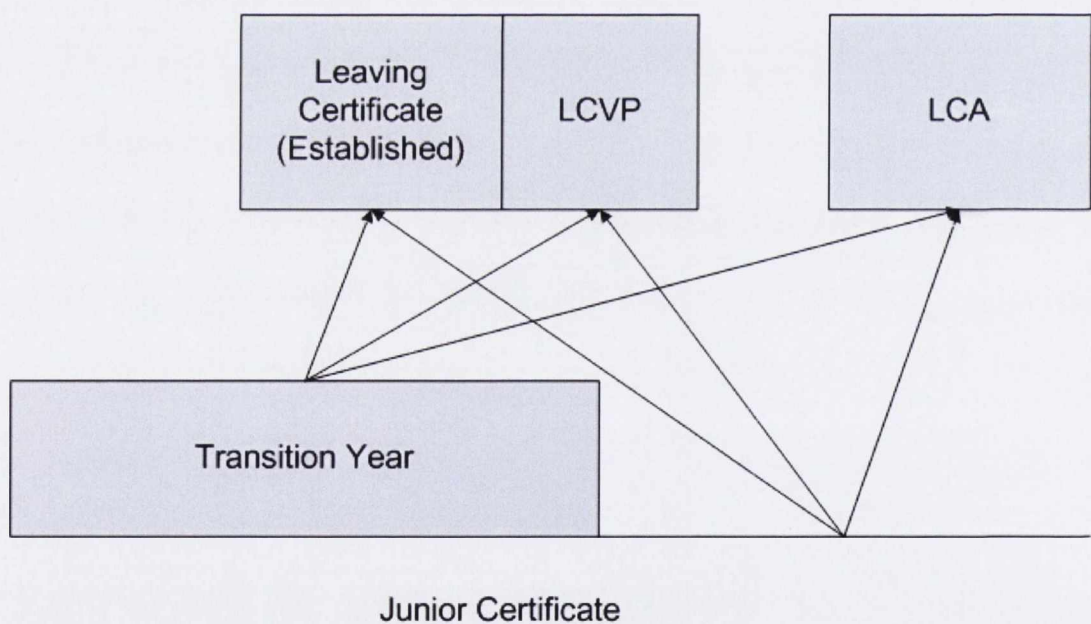
Figure 4.3 The Irish Education System in 2005.



Source: Government of Ireland, 2005, Department of Education and Science, Statistical Report, 2004-2005.

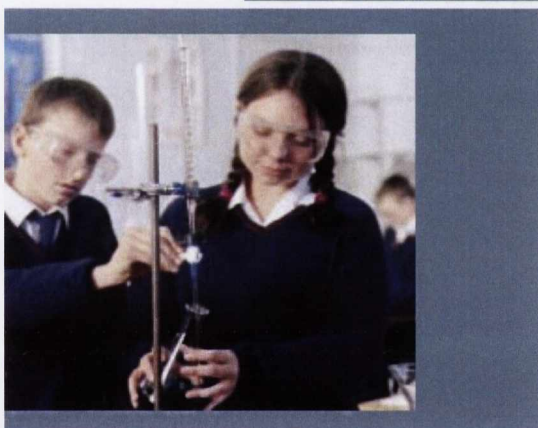
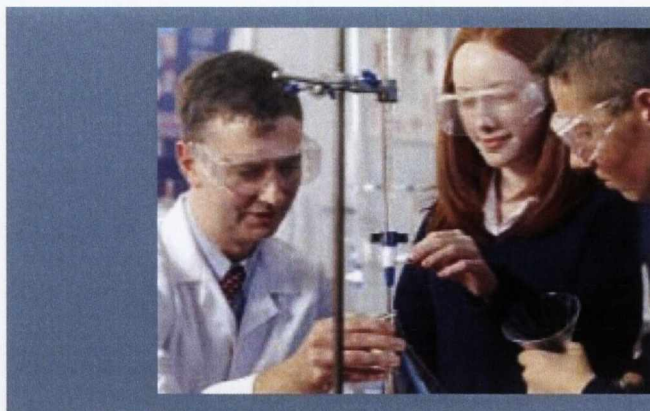
The two year Leaving Certificate programme, renamed *Leaving Certificate (established)* was to become the lynchpin programme flanked by a number of extra optional programmes: *Transition Year (TY)*, *Leaving Certificate Vocational Programme (LCVP)* and *Leaving Certificate Applied (LCA)*. LCVP was regarded as an enhanced Leaving Certificate.⁸⁴ The LCA programme remained a ring-fenced two year alternative programme offered as a parallel track.⁸⁵ Senior cycle was therefore divided into six pathways of progression from completion of the Junior Certificate examination at the end of lower secondary education (Figure 1.13). It is science and mathematics within this academic *Leaving Certificate (established)* programme that is the focus of this study. Students typically choose six or seven subjects. The syllabus for each is presented by the DES each year in a publication called *Rules and Programme for Secondary Schools*.⁸⁶

Figure 4.4 Six pathways through senior cycle 1994-2005.



Source: Author.

4.5 Curriculum & Pedagogical Reform in Senior Cycle Science Education



Science photographs: Department of Education and Science, Annual Report 2002

Post-16 non-compulsory science education in *Leaving Certificate (established)* changed in several ways over the forty five year period of the study. This section considers some of the changes in science education and proceeds to explore changes in each of the subject matter areas of physics, chemistry and biology with respect to pedagogy and assessment.

In the nineteen sixties, with the full scale promotion of the sciences, laboratory grants were provided and new laboratories were built when the capital programme of the Department of Education commenced in 1966.⁸⁷ Senior cycle science was offered at

national level as a palette of seven distinct subjects out of a possible twenty four subjects presented: physics, chemistry, physics and chemistry, botany, general science, agricultural science and physiology and hygiene.⁸⁸ Analysis of the 1967 examination papers, by Madeus and McNamara (1970) concluded that they required only rote learning from students.⁸⁹ A survey of science teachers by O’Buachalla (1972) showed that knowledge rated higher than experimental skill.⁹⁰

The Irish Science Teachers’ Association (ISTA) the voluntary subject association was founded by George Lodge in 1961.⁹¹ The association published a quarterly journal called *Science* and made occasional submissions to the DES on a number of science related policy documents.⁹² However, the ISTA had neither the resources nor the political clout to put the need for long term policy on science teacher education onto the national agenda for educational change. Research into the quality of science teaching conducted by Daly (1972), concluded that science teaching was largely didactic with a focus on rote learning.⁹³ This examination-centred focus was to remain as the predominant paradigm, supported by the findings of the OECD *Country Review of Ireland* 1991 study, even though the rhetoric of more learner-centred approaches were being espoused in all reforms in the early years of this century.⁹⁴

From 1994 onwards a national campaign was mounted to promote science and to uplift a declining interest in the physical sciences. Forfás, set up as a national policy agency, raised awareness of the importance of science through a number of initiatives between 1997 and 2005, among them *Science Week Ireland*, a national showcase of public events and the *Discover Science and Engineering* (DSE).⁹⁵ Teaching science for the enquiring mind was supported nationally, from 1964-2005, by a prestigious annual *Young Scientist Competition*, sponsored initially by the national airline *Aer Lingus* and later by the telecommunications company *ESAT Telecom*.⁹⁶

4.5.1 Leaving Certificate Science Graduation Rates

Students graduating from *Leaving Certificate (established)* science subjects took a final three-hour written examination paper at higher or lower levels of specialisation. Figure 4.5, Figure 4.6 and Figure 4.7 give the uptake for Leaving Certificate physics, chemistry and biology respectively, from 1960-2005. The table of data, compiled, by the author from national statistics reports, may be found in Appendix V. The graph for physics shows a steady increase from 12.8% in 1960 to 19.2% in 1984, after which the pattern declines. Chemistry data also indicated a steady increase from 14.8% in 1960 to 19.8% in 1984 after which the subject declined to 16% in 2005. Biology held a strong position as an attractive Leaving Certificate subject from 1971 to 2005, with uptake varying from 43.9% to 52.8%, ending up as the sixth most popular subject in Leaving Certificate in 2005.

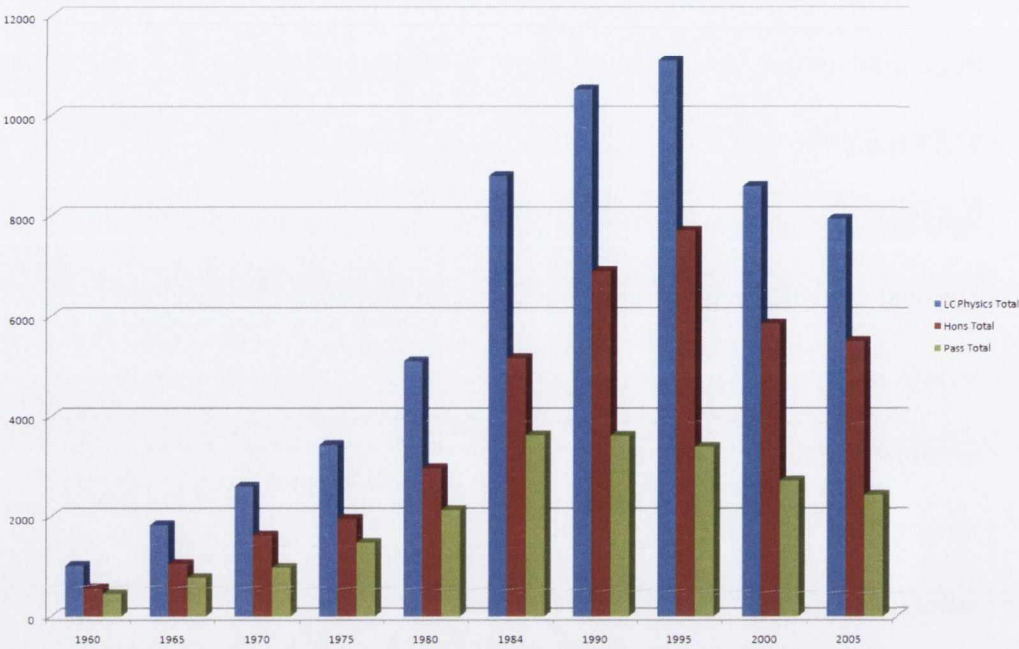
4.5.2 Reform in *Leaving Certificate (established)* Physics

Between 1960 and 2005 physics underwent four reforms: one in 1963 with a minor revision in 1969, a major reform in 1984 and another major reform in 2000. Changes reflected moving from a theoretically presented subject to a more experimentally based subject and involved deepening and broadening the knowledge base of each of the main topics: *mechanics, sound, light, heat, waves, electricity, magnetism and modern physics*.

Physics Syllabus 1963 (1969)

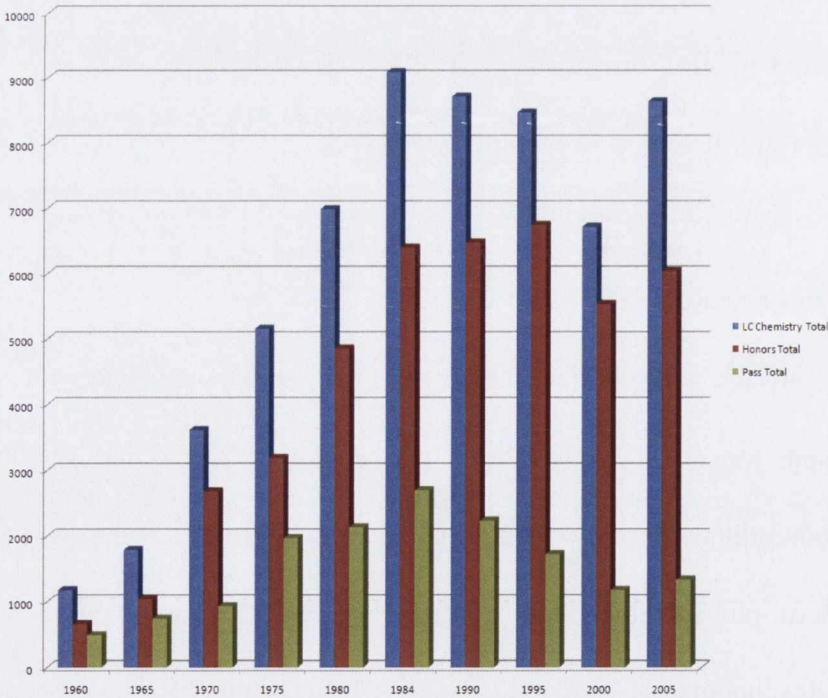
The physics syllabus of 1959-1960 was a basic syllabus with limited content.⁹⁷ The syllabus was offered at two levels of specialisation, pass and honours. The reform of 1963 included the wave nature of light and sound while the section on the atom was updated to modern physics, including radioactivity and the photoelectric effect.⁹⁸ Senior cycle physics underwent a revision in the introduction of the new *Leaving Certificate* in 1969/71.

Figure 4.5 The number of students graduating from Physics at higher and ordinary levels of specialisation 1960-2005.



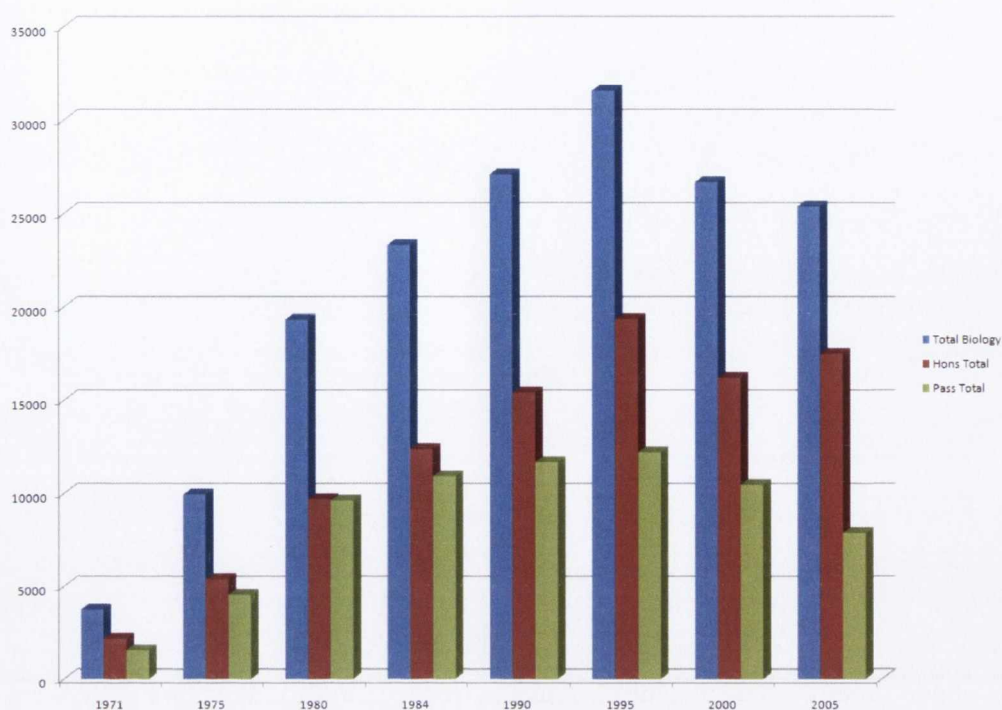
Source: Compiled by Author from Statistical Reports, Department of Education and Science, 1960-2004 and the State Examinations Commission, Annual Report, 2005.

Figure 4.6 The number of students graduating from Chemistry at higher and ordinary levels of specialisation 1960-2005.



Source: Compiled by Author from Statistical Reports, Department of Education and Science, 1971-2004 and the State Examinations Commission, Annual Report, 2005.

Figure 4.7 The number of students graduating from Biology at higher and ordinary levels of specialisation 1960-2005.



Source: Compiled by Author from Statistical Reports, Department of Education and Science, 1960-2004 and the State Examinations Commission, Annual Report, 2005.

The syllabus presented experimental work that the teacher could demonstrate or the students could carry out, depending on available resources:

As far as is practicable experiments should be done by pupils but where apparatus is hazardous, elaborate or expensive, it may be better to use a demonstration. Pupils can often help during demonstrations, as, for example, by taking readings and this should be encouraged. Where it is not practicable to have several sets of an item of apparatus the class may be organized into a number of groups each doing a separate experiment in weekly rotation; this is particularly suitable in the more advanced stages of the course.⁹⁹

The text-book widely used at the time, *Leaving Certificate Physics* by The Christian Brothers, presented topics using only technical and mathematical language.¹⁰⁰ According to Madeus and McNamara's (1970) review of the examination papers the Leaving Certificate physics examination offered little by way of application of knowledge or higher order critical thinking:

the main finding of our analysis is that both the pass and honours examinations stressed the recall of specific items of information at the expense of higher order, more general, abilities and at the expense of command of the scientific method.¹⁰¹

On the 30th January 1964 the Minister for Education Dr. Patrick Hillery T.D. indicated that there were 193 secondary schools offering Leaving Certificate physics, with 43 teaching physics through Irish and 148 teaching through English.¹⁰² It was noted that the number of schools with an honours science graduate on their staff was eighty one.¹⁰³ This was in a year in which there was a total of 460 secondary schools in the country.¹⁰⁴

Physics Syllabus 1984

A major reform in 1984-1986 brought mandatory practical work into the teaching of physics and a list of twenty eight student experiments was provided.¹⁰⁵ The broad aims of the syllabus were to gain an understanding of the fundamental principles of physics and their applications to everyday life.¹⁰⁶ The 1984 syllabus suggested that the teaching of physics should include modern methodologies and develop school-industry partnerships:

Teachers should also use practical demonstrations where appropriate: they may find the computer a useful aid in such work. They are recommended to arrange liaison with local industry so that the applications of physics in technology may be observed. Teachers, in addition, are encouraged to refer to the historical development of the subject where appropriate. In this regard reference should be made to the lives and work of great physicists.¹⁰⁷

Physics Syllabus 2000

The new syllabus introduced in 2000, for examination in 2002, was an attempt to modernise the subject and included physics for the enquiring mind with some applied physics.¹⁰⁸ The *Equality Committee of the DES* produced a handbook for physics teachers, to offer a better explanation of physics concepts using accessible language.¹⁰⁹ The need for a range of teaching strategies was highlighted:

STS can be introduced into the classroom by a range of teaching strategies, including class discussions; debates; projects; role-playing; research using newspapers and magazines; analysis of videos; visits to local industries, hospital, museums etc. and active reading.¹¹⁰

The *Chief Examiner's Report* 2002 observed that pupils had difficulty in making the connection between physics knowledge and everyday experiences:

Students need to integrate their knowledge of physics with everyday experiences to enhance their understanding of the STS aspect of the syllabus.¹¹¹

The *Chief Examiner's Report* 2005 noted that while experimental questions were well answered that few candidates were using data logging methods:

Teachers should encourage their students to understand the principles of physics using a variety of techniques.....Candidates need to experience a wide variety of practical and relevant situations in which they can apply their knowledge of the principles and concepts of physics.¹¹²

By 2005 physics was still unattractive to students, both boys and girls (especially girls), and students clearly needed a more explicit connection between the fundamental laws and concepts of physics and everyday experience.

4.5.3 Reform in *Leaving Certificate (established)* Chemistry

Chemistry underwent four reforms: one in 1963, a minor revision in 1969, a major reform in 1983 and another in 2000. Chemistry changed from a focus on pure chemistry to a combination of pure and applied chemistry, in a ratio of 70:30, with an emphasis on the need for students to engage with mandatory experiments. The syllabuses became less theoretical and more related to real world applications, although these tended for the most part to be industry-related exemplars.

Chemistry Syllabus 1963 (1969)

Senior cycle chemistry in 1959/60 was divided into pass and honours material.¹¹³ The syllabus was changed in 1963 for examination in 1965. This time the syllabus was considerably more detailed and was sub-divided into ten topics for the pass course with an additional ten topics for honours chemistry.¹¹⁴ A further revision in 1969 saw the subject presented as fifteen topics, with higher level material in italics, and a more explicit emphasis on the experimental aspect of the subject.¹¹⁵ There was a marked increase in the

number of students taking chemistry from 1970 onwards. In the early seventies the textbook *Leaving Certificate Chemistry* by the Christian Brothers was, similar to its physics companion volume, rich in theory but with little experimental detail.¹¹⁶ Madeus and McNamara (1970) found the chemistry examination papers also designed for rote learning, with little comprehension and virtually no higher order thinking:

a pass student could have gained fifty per cent if he had memorised the laboratory preparation of five common gases. Students' notebooks showed that the preparation of these gases had been dictated to them by their teachers, while A.E. Sommerfield's *Chemistry for the Leaving Certificate pass and honours...spells out the preparation of these same five common gases.*¹¹⁷

Chemistry Syllabus 1983

A major reform in 1983, for first examination in 1985, saw the subject categorised into fourteen topics.¹¹⁸ Each topic had recommended student experiments. The ISTA journal *Science* started to include articles on how to teach aspects of the subject. Kennedy (1986) wrote an article on practical work in the chemistry syllabus.¹¹⁹ Simmie (1990) recommended making the teaching of chemistry more interesting through gas syringe experiments.^{120,121} Uptake in chemistry increased until the mid-nineteen eighties (19%) after which it began to show a pattern of decline. The textbooks at the time reflected the change in emphasis in the syllabus and had plenty of industrial applications.^{122,123} A number of teaching videos were also presented to assist with experimental work.¹²⁴ Teaching methods were largely didactic and Childs (1983) expressed this as a central concern at the ChemEd Conference in 1983:

sadly, it has been possible --- indeed it has probably been the norm --- for students to follow a two year chemistry course, following a three year general science course, and obtain honours in the examination without ever handling chemicals and apparatus in a laboratory.¹²⁵

Chemistry Syllabus 2000

The reform of 2000 sought to present a 70:30 ratio between pure and applied chemistry and to introduce a list of mandatory student experiments.¹²⁶ It was divided into a core of nine units and two options. Experiments were presented as a list of mandatory student experiments: twenty eight for higher level and twenty one for ordinary level. The social and applied aspects were mostly industrial and technological in nature with few everyday contemporary exemplars. Uptake of chemistry declined from 19% in the mid-nineteen eighties to 16% by 2005.¹²⁷ The reform in 2000 was supported by a wealth of documentation, most of which was available on the web-site of the support service.^{128,129} Documentation included the syllabus itself, the NCCA Teacher Guidelines and a Handbook produced in association with the Equality Unit of the DES.¹³⁰

Assessment of the chemistry programme continued as a three-hour, externally marked, written examination at the end of two years. The *Chief Examiner's Report* 2002, identified a number of areas where consistent difficulties were found:

explaining atomic spectra; describing and accounting for trends in the periodic table; connecting the observations from the conclusion drawn from Rutherford's gold foil experiment; instrumentation and organic chemistry including the mandatory experiments.¹³¹

The mathematical competence required in answering chemistry papers was reduced and helped contribute to the overall improvement in grades awarded.¹³² The *Chief Examiner's Report* of 2005 noted that the decline in chemistry had begun to reverse and while welcoming this development sought to explain it:

interventions included a rebalancing of content and level of accessibility of the examination papers in 2000 in response to the results of research on examinations carried out by the Education Research Centre. Revised syllabi for Leaving Certificate Chemistry were introduced for examination in 2002 as part of the Physical Sciences Initiative. This initiative also incorporated a major in-service programme for teachers as well as enhanced resources for schools.¹³³

Future success with chemistry was dependent on the ability of students to understand abstract concepts and to manage the mathematical component of the subject.

4.5.4 Reform in Leaving Certificate (established) Biology

Biology, from its introduction in the new Leaving Certificate of 1969/71, only underwent one minor revision, in 1975, and remained essentially unchanged until a major reform in 2002, which was first examined in 2004. All biology reforms emphasised the importance of field-work. The main change was the new emphasis placed on experiential teaching and learning and mandatory experiments.

Biology Syllabus, 1969 (1975)

The senior cycle biology course was first introduced in 1969 for examination in 1971.¹³⁴ A common syllabus was presented for all students. Duhig (1965) reported in *Science* on the OECD seminar on the reform of biology teaching in La Tour de Peilz, Switzerland 4th-14th September 1962.¹³⁵ Teaching topical subjects, like ecology, posed its own challenge as recounted by Kelly (1965).¹³⁶ The syllabus underwent a revision in 1975.¹³⁷ The revision added three new sections and indicated a suggested time allowance for each topic (Table 4.7).¹³⁸ The first textbooks used were black-and-white productions.¹³⁹ After the course was revised in 1975 the textbooks included investigations and later, by the nineteen eighties, these had become full colour productions.^{140,141}

Biology syllabus 2002

The 1975/77 revised syllabus was to remain for twenty seven years until a new reform of the senior cycle biology syllabus for Leaving Certificate took place in 2002.¹⁴² The reasons given included the need to modernise the subject, to shorten a course that was described as too long and to take the needs of ordinary level students into account.¹⁴³ The new syllabus had a new emphasis on biochemistry reflecting changes in modern biology internationally. The syllabus was sub-divided into three categories: *the study of life; the cell and the organism*. In 2004 a number of teachers shared their action research exploration of teaching biology in senior cycle.^{144,145} A number of supports were put in place, including a

national support service and additional documentation from the NCCA.¹⁴⁶ Official documents included the *NCCA Laboratory Handbook* for Biology Teachers.¹⁴⁷

Table 4.7 Suggested time allowance for topics in biology syllabus, 1975-1977.

TOPIC	Suggested Time Allowance
1. Characteristics of Living Organisms	2 class periods
2. Cell Structure	8-12 class periods
3. Diversity of Living Organisms	40-45 class periods
4. Physiological Processes	70-80 class periods
5. Microbiology	20 class periods
6. Genetics	40-45 class periods
7. Co-ordination	28 class periods
8. Reproduction and Development	50 class periods
9. The Soil	6 class periods
10. Ecology	19+ class periods

Four circular letters were sent to schools between 2000 and 2002 heralding the introduction of the syllabus.¹⁴⁸⁻¹⁵¹ The emphasis was on experiential learning through hands-on practical activity. Placing practical work onto the agenda proved difficult:

There is continuing evidence of candidates' unfamiliarity with experimental work as shown by answering in Questions 8, 14 (a) and (b), 15 (a) and (c) and Questions 9(b) and 15(a) at Higher Level.¹⁵²

There is continuing evidence of candidates' unfamiliarity with experimental work as shown by the answering in Questions 2, 9(c), 11(a) at Higher Level and 10(b), 11(c), 15(a), (d) at Ordinary level. There is additional evidence for this situation arising from much correspondence from pupils and parents following the examination where it is often stated that practical work is not a feature of the pupil's experience in school.¹⁵³

After the first examination the *Chief Examiner's 2004 Report* indicated that the position appeared to be improving:

While the standard of answering in Section B was reasonably good and would lead one to conclude that practical work is being undertaken in schools, the standard of the answers to questions on laboratory experiments in Section C was poor.¹⁵⁴

By 2005 the two significant issues identified that needed further attention in biology appeared to be student's access to mandatory experiments and the need to change the assessment component to include these experiments.

4.5.5 Summary of Science Education Reforms

In summary the official documentation with respect to physics, chemistry and biology, syllabuses, teacher guidelines and Chief Examiner's Reports were all promoting an experimental, experiential and activity-based approach to teaching for student learning.

The syllabuses suggested a wide variety of resources and teaching and learning strategies:

The activities column provides a pedagogical approach to the syllabus by outlining the relevant demonstrations and by indicating where problem-solving is required. Where resources permit, the use of spreadsheets, data-logging, computer-aided learning, modelling and simulation is recommended. Slides, posters and videos are excellent resource materials and their use in implementing the syllabus is recommended. Additional activities may be included where appropriate.¹⁵⁵

They recommended demystifying the subjects and relating topics to everyday real world experiences:

It is important to include personal, medical, biological and social examples of physics as well as mechanical and technical examples so that the place of physics in the everyday world can be appreciated.¹⁵⁶

The NCCA *Teacher Guidelines* for these subjects all stressed the importance of using a variety of teaching strategies with a focus on student learning and experimental work.

They also indicated that these methodologies signalled a change from previous traditionally inherited textbook-led practices:

It will require from teachers an openness, a willingness to learn, to keep up to date and to admit to the limits of knowledge.¹⁵⁷

One of the primary aims in the production of these detailed guidelines is to allow the teaching of the course to be syllabus led rather than textbook led. Teachers are strongly advised to familiarise themselves with the syllabus content and these guidelines so as to promote professional teaching methods.¹⁵⁸

Teachers should be able to give equal emphasis to ordinary level and higher level students, so that both groups enjoy, and gain from, the experience. Teachers should demystify the subject and make it attractive to students at both levels. This is a challenge to chemistry teachers that must be accepted if the numbers taking the subject are to increase.¹⁵⁹

These official documents, syllabuses and teacher guidelines, were in agreement with the national quality assurance framework of the inspectorate, LAOS 2003, and other documentation from the inspectorate:

Teaching is a complex activity that demands a high level of knowledge and a wide range of pedagogical skills and personal attributes....Teachers are required to have a sound conceptual and practical understanding of the subject areas they are teaching...Reflective teachers analyse their practice: they review the quality of their planning (and) they consider the quality of the pupils' learning.¹⁶⁰

Analysis of comments selected from the *Chief Examiner's Reports* suggested that many students did not generally understand the abstract concepts and principles of these subjects and were unable to integrate subject knowledge with everyday experience. Biology students, in particular, did not appear to be familiar with experimental work, while there was little evidence to suggest that datalogging equipment was being used to any great extent, by science students generally, to tabulate data from experiments.

By 2003-2004 science syllabuses in Leaving Certificate, in physics, chemistry and biology, were all 180-hour courses, at higher or ordinary levels of specialisation, and were typically taught as five class-periods per week over two years. They were each assessed at the end of the two year period by a written three hour externally assessed examination. Teachers were not involved in summative assessment of their own students for the purpose of matriculation to higher education. The main curricular reforms common to each, in terms of pedagogy and assessment, may be summarized as follows:

- The new syllabuses had a 70%: 30% weighting in favour of pure science. The 30% weighting for applied science was sub-divided into science applications and technology (22.5%) and science for the citizen (7.5%).
- NCCA Teaching Guidelines stressed the need for modern methods of teaching and learning. For example, the NCCA Guidelines for Biology suggested using ICT:
spreadsheets, data logging, computer aided learning, modelling and simulating, CD's, email and Internet.¹⁶¹
- Each subject had a list of mandatory student experiments in the syllabus: 27 for physics, 24 for chemistry and 22 for biology at higher level. A section was set

aside for questions specifically related to mandatory experiments on each examination paper.

- Teachers were given inservice support and schools received grant aid to purchase data logging equipment. However, this ICT component was not obligatory:

students will be given full recognition for carrying out mandatory experiments using computer interfacing and other modern methods of computer-aided technology. However, this is not obligatory.¹⁶²

- Issues of health and safety gained prominence with teachers obliged to complete risk assessment sheets for the laboratory. Two circular letters were sent to schools in this regard.¹⁶³⁻¹⁶⁴ Safety guidelines available for schools included two Departmental documents.^{165,166}

The official documentation showed sufficient clarity and coherence between them with regard to pedagogy and assessment and the changing conception of teaching. They were all congruent in that older inherited practices were being challenged and a culture change was being required of teachers and schools. This culture change required subject knowledge to be constructed using a variety of activity based and differentiated learning approaches. However a disconnection was found between the rhetoric of these documents and the actual examination papers. Analysis of the Leaving Certificate Physics, Chemistry and Biology examination papers, at higher level, for 2004 showed a number of discrepancies (Table 4.8).¹⁶⁷⁻¹⁶⁹ While critical thinking and higher order thinking were in fact possible, given the highly conceptual nature of these syllabuses, and some parts of all questions in the examination papers required some higher order thinking, such as application of knowledge, it is questionable as to what extent the papers could be construed as testing critical thinking. In a similar way the 70:30 divide was not found in each question with respect to the ratio of the pure and applied nature of the topic.

Little effort was made in the syllabus or in the examination papers to relate the principles of physics or chemistry to everyday life. Occasionally there was a question based on recognising the photograph of a scientist but it was of little value, with a total of six marks from a total of four hundred allocated to it. It may be concluded that clarity, coherence and congruency between the *policy as text* documents was not totally assured for the *Leaving Certificate (established)* science programmes at senior cycle.

4.6 Curriculum & Pedagogical Reform in Senior Cycle Mathematics Education

From the nineteen sixties onwards mathematics was offered as part of a traditional *Leaving Certificate* at two levels of specialisation. By 2005 this had evolved to three levels, higher, ordinary and foundation, with higher level being the least popular subject in *Leaving Certificate (established)*.¹⁷⁰ Mathematics was a requirement for matriculation and as a result, by 2005 the subject was taken by 96.5% of students (52,178 students) in senior cycle.¹⁷¹ Curriculum reforms in mathematics involved a deeper and broader study of the subject and an increasing awareness of the need for multiple levels of specialisation to suit the diversity of learner. Ireland ideologically embraced the Bourbakiste school of mathematics (*new mathematics*), in the nineteen sixties, which emphasised a non-contextualised abstract approach to the subject. This essentialist philosophy was largely to remain intact in the forty five year period of this study. The *new mathematics movement* was driven as a top down reform by the DES inspectorate in 1964-1965.^{172,173} The OECD-sponsored two-week *Royaumont Conference* in Paris in 1959 is described by Oldham (1992) as a seminal meeting for developments in mathematics education.¹⁷⁴ Oldham (1991) also revealed that the number of countries following the *new mathematics* approach was quite small:

For Ireland, however, the surprise lay in the fact that the sub-cluster was so small; Irish mathematics educators had tended to assume that the Bourbakiste type of curriculum was the international norm.¹⁷⁵

Table 4.8 Key features of science curricular reforms mentioned across policy documents 2000-2004.

Reforms	Syllabuses			Teacher Guidelines			Exam	Papers	
	Physics	Chem	Biol	Physics	Chem	Biol	Physics	Chem	Biol
Critical Thinking	√	√	√	√	√	√	?	?	?
Mandatory Experiments	√	√	√	√	√	√	√	√	√
70:30 Pure/applied	√	√	√	√	√	√	?	?	?
Related to everyday life	X	X	X	√	√	√	?	?	?
DataLogging	X	X	X	√	√	√	X	X	X
Health & Safety	√	√	√	√	√	√	—	—	—

KEY:

Biol = Biology; Chem = Chemistry; Exam = Examination

√ Yes, mentioned ? questionable — not relevant X not mentioned

Coinciding with the introduction of a new junior cycle mathematics syllabus the *NCCA Senior Cycle Mathematics Course Committee* was reconvened in 2002.¹⁷⁶ At the time it proposed no change. Senior cycle would benefit from a number of knock-on effects of the new teaching methods in junior cycle. A circular letter was issued to schools informing teachers of the new content of the junior cycle mathematics course.¹⁷⁷ This thinking was reversed in October 2005 when the NCCA declared a full scale reform of senior cycle and signalled that radical change was required.¹⁷⁸ It recognized a need for a change of culture:

A change of culture is required, together with a change in practice. Past experience, nationally and internationally, tells us that a longer term strategy of implementation and support is required.¹⁷⁹

The review identified as core issues the low uptake of higher level mathematics, the low grades in ordinary level and the emphasis on routine procedures in the teaching of mathematics. Conway (2005) argued that redefining mathematics education was an international movement:

The cultural pressure to redefine mathematics emanates from a variety of sources, including disenchantment with the overly abstract focus of the now longstanding “new” or “modern” mathematics curricular culture, alarm among the business community (and some educators) at students’ limited capacity to apply knowledge in new contexts, pressure from the learning sciences to revise our deeply held ideas and assumptions about learning and mathematical understanding, the unprecedented elevation of international comparative test results onto government and cabinet tables, and deep concern about perceived and/or actual gender, socio-economic status (SES) and ethnicity gaps on mathematics achievement tests.¹⁸⁰

Inherited practices in mathematics teaching, reported by Lyons et al, 2003, indicated a strong essentialist epistemological framework with a teacher-centred culture.¹⁸¹ The voluntary subject association, the *Irish Mathematics Teachers Association* (IMTA), founded in 1964, remained active throughout the period of this research.¹⁸² It held local branch meetings, an annual general meeting and published a newsletter *Eol Oidí na hEireann Irish Mathematics Teachers’ Association Newsletter*, approximately three times a year. The IMTA newsletter had articles on subject content and a smaller number of articles on how to teach topics to different ability levels. The fall-out from the *new mathematics* approach became obvious in the nineteen seventies and eighties as teachers noted a large cohort of students being left behind in mathematics.^{183,184} Newsletters had the occasional article on teaching for understanding but the greatest emphasis was reserved for solutions to examination papers.¹⁸⁵⁻¹⁸⁷

4. 6.1 Reform in Leaving Certificate (established)

Leaving Certificate (established) underwent three major reforms in 1964, 1976 and 1992 and moved from two to three levels of specialisation.

Mathematics Syllabus 1964

The mathematics syllabus in 1959/60 involved knowledge of cones and spheres, solving and graphing equations in two unknowns, knowledge of Book VI of Euclid's elements and the cosine rule.¹⁸⁸ The *new mathematics* introduced into Leaving Certificate in 1964 included an extensive range of new topics to be taught with an emphasis on abstract mathematics.¹⁸⁹ This syllabus change of 1964 was extended in the new Leaving Certificate in 1969 to include groups, probability and trigonometry.

Mathematics Syllabus 1976

The 1976/78 reform copper-fastened the abstract focus of the syllabus and introduced a standard to the higher level paper that over time became impossible to sustain.¹⁹⁰ The detailed six page syllabus was accompanied by sixteen pages of exemplars. In 1980 computer studies was introduced as an optional element coinciding with a growing interest nationally in computer programming.¹⁹¹ This optional section required 35 hours of additional study and was nationally certified. The computer studies option only lasted until the 1992 reform after which it was removed from the syllabus.

Mathematics Syllabus 1992/94

In 1990, coinciding with the difficulties experienced by the under-achiever in senior cycle mathematics, the *ordinary alternative*, a less theoretical level was introduced for first examination in 1992.¹⁹² It attracted approximately 6,000 students each year, 10% of the total cohort. The 1992/1994 reform of senior cycle mathematics, offered three levels of specialization, *higher*, *ordinary* and *ordinary alternative*.¹⁹³ The ordinary alternative course was adjusted in 1997 and renamed the *foundation level* course.¹⁹⁴ NCCA teacher guidelines were produced to assist teachers in implementing the course and a series of one-day inservice support events were provided by the DES, through local education centres.¹⁹⁵ The higher level course was aimed at more able students and consisted of a core

and options.¹⁹⁶ All Leaving Certificate courses emphasised the importance of fostering a spirit of *inquiry and critical thinking*.¹⁹⁷ The *higher level* mathematics course aimed to:

deepen their understanding of mathematical ideas, to encounter more of the powerful concepts and methods that have made mathematics important in our culture, and to enhance their enjoyment of the subject.¹⁹⁸

The *ordinary level* course was presented as a core and several options of which the students had to choose one. It was designed for students who wanted a basic proficiency in the subject and might use it in a practical way:

(it will be) their last formal encounter with mathematics (and those for whom it will be) essentially a service subject, providing knowledge and techniques that will be needed in future for their study of scientific, economic, business and technical subjects.¹⁹⁹

The *foundation level* course was designed as a terminal course and was a practical programme, with extensive calculator use and real life relevance.²⁰⁰ The course aimed at providing a grounding in everyday mathematics:

a good lively and relevant mathematical education for those whose future use of mathematics will be in real-world contexts rather than in further technical study.²⁰¹

4.6.2 Chief Examiner's Mathematics Reports

Chief Examiner's Reports in LC mathematics were presented in 1995, 2000, 2001 and 2005. The *Chief Examiners Report* 2000 critiqued mathematics education in senior cycle and highlighted a number of areas where routine mechanistic teaching was failing to deliver higher order thinking and a deeper understanding of mathematical concepts. However, it noted an increase in the uptake of higher level, from 11.2% in 1993 to 18.1% in 1997.²⁰² It concluded that candidates lacked resilience and were not prepared to persevere with a problem:

candidates displayed less perseverance than in previous years – they tended to stop and abandon work when they hit barriers, they rarely offered second attempts and showed weak will to tease out problems. The fact that straightforward early parts of questions were left unfinished and that candidates often wasted time over-explaining themselves suggests that shortage of time was not the root cause of this.²⁰³

With regard to the ordinary level paper there was evidence of lack of understanding of concepts and a high failure rate indicating the unsuitability of this level for a significant number of candidates.²⁰⁴ The report argued that this was due to a range of factors:

- A recognition that students were entering senior cycle mathematics with an inadequate grasp of fundamental concepts.
- The suggestion that many candidates taking Ordinary level should, in fact, be taking Foundation level.
- The possibility that students were not achieving in ordinary level mathematics due to the fact that many were involved in part-time work:

There is increasing anecdotal evidence from teachers that the amount of time and energy being devoted by students to part-time work has increased dramatically over a short period of time....as a consequence of this, teachers are reporting increased levels of: absenteeism from class, failure to complete or even attempt homework (and) lack of energy and concentration, due to long hours of work and late-night activity.²⁰⁵

The Chief Examiner's Report 2005 noted the uptake in higher level had increased in the nine years since the new syllabus was introduced to 18.1% which, while welcomed, fell far short of the anticipated 25% uptake.²⁰⁶ Similarly, the cohort for foundation level, at 10%, fell short of the anticipated 25%. The Foundation level course was failing to attract a large proportion of its intended cohort and candidates showed *little evidence of much understanding*.²⁰⁷ Ordinary level candidates had difficulty understanding concepts:

Weaknesses, by and large, relate to inadequate understanding of mathematical concepts and a consequent inability to apply familiar techniques in anything but the most familiar of contexts and presentations.²⁰⁸

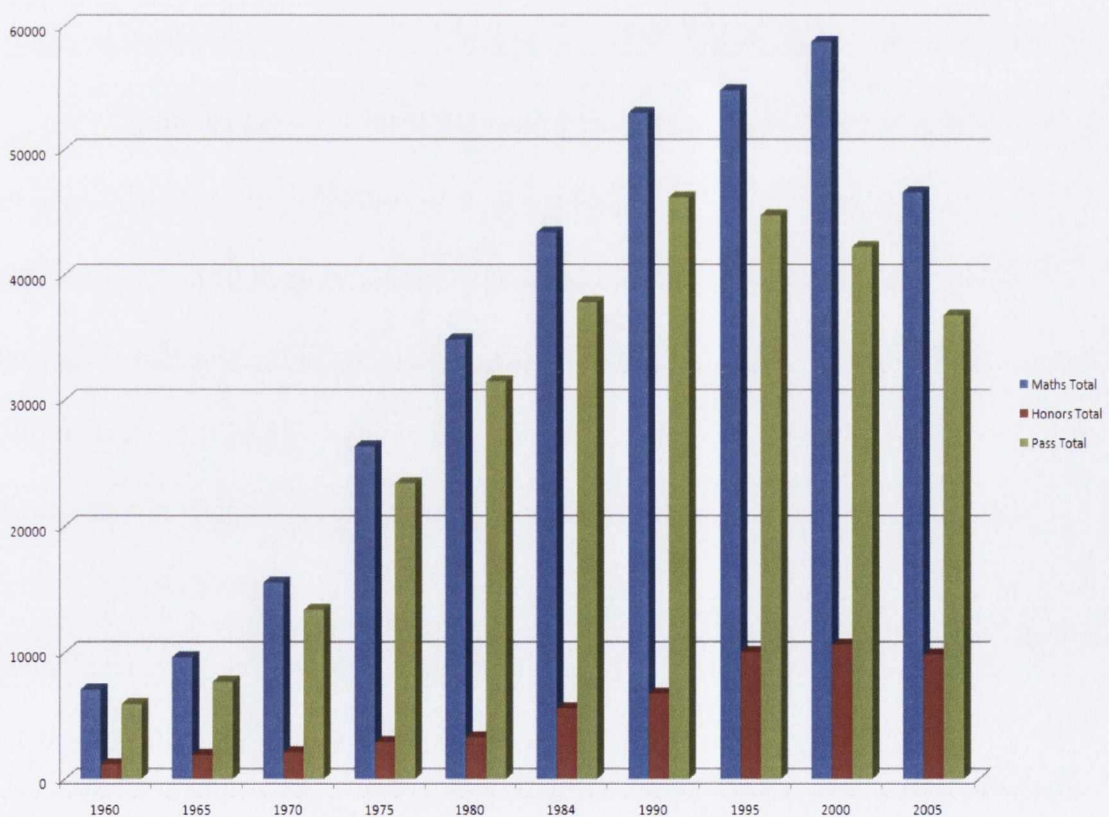
Higher level candidates also appeared to have difficulty with anything other than routine and familiar applications:

examiners have been commenting on a noticeable decline in the capacity of candidates to engage with problems that are not of a routine and well-rehearsed type.....any question that requires the candidates to display a good understanding of the concepts underlying these procedures causes unwarranted levels of difficulty.²⁰⁹

4.6.3 Graduation Rates in Leaving Certificate (established) Mathematics

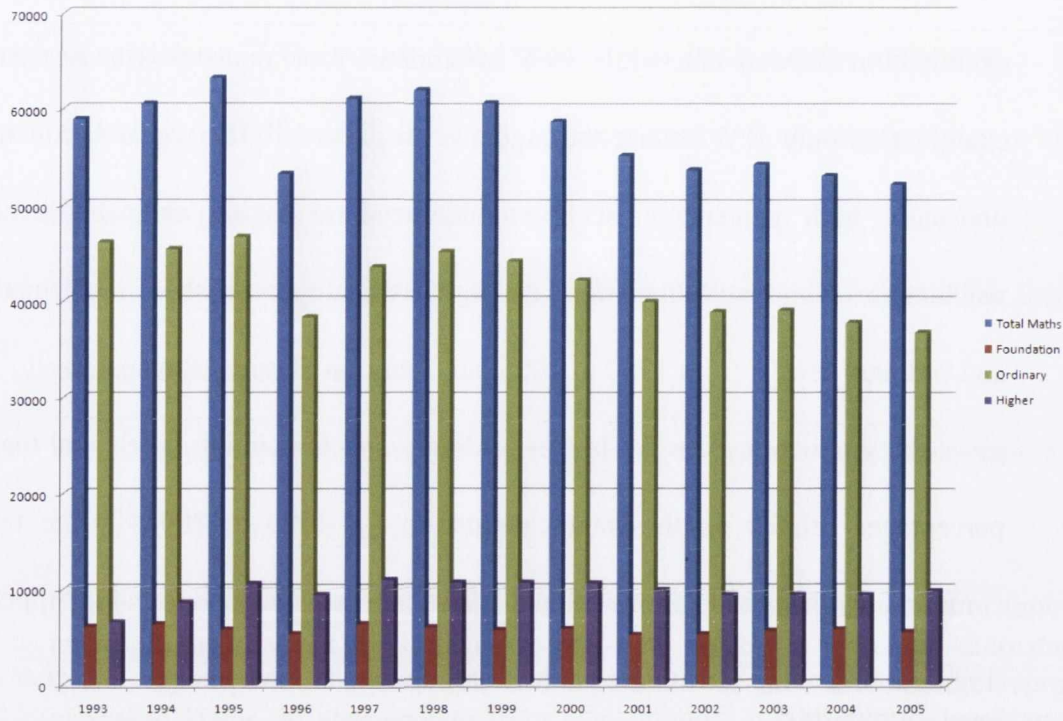
Research findings by Martin and Hickey (1991) of the 1991 *Leaving Certificate* examination showed that while 99% of students took mathematics as a subject in the examination only 12% choose the higher level papers.²¹⁰ The research concluded that an unusually high percentage of able students were taking ordinary level papers in mathematics. Graduation rates for Leaving Certificate (established) mathematics at higher and ordinary levels, from 1960 to 2005, are found in Figure 4.8 respectively.²¹¹ Figure 4.9 gives the graduation rates for higher, ordinary and foundation levels and their respective percentages relative to the total candidature for 1993 to 2005.²¹² The table of data, compiled, by the author, from national statistics reports may be found in Appendix VI.

Figure 4.8 Leaving Certificate graduation numbers in mathematics, at higher and ordinary levels, 1960-2005.



Source: Compiled by the Author from Statistical Reports of the DES and the State Examinations Commission, Annual Report, 2005.

Figure 4.9 Leaving Certificate graduation numbers in mathematics, at higher, ordinary and foundation levels, 1993-2005.



Source: Compiled by the Author from Statistical Reports of the DES and the State Examinations Commission, Annual Report, 2005.

4.7 Teacher Reform and Opportunities for Professional Learning

In-career teacher education went through an extensive number of changes in the forty five year period of this research study. Inservice support ranged from evening courses, to half-day and one day events, delivered by the inspectorate in the nineteen sixties and seventies, to full day INSET (inservice education and training) delivered to teachers by teachers in the nineteen eighties, to the formation of over thirty support services in the nineteen nineties and early years of this century. These support services assisted with the implementation of subject reforms, programme reforms, generic developments, special needs education, school development planning, induction and educational leadership. It marked the changing role of the state as provider of inservice education to that of adviser, financial supporter and evaluator of inservice teacher education.

The period signalled the changing role of the teacher from *craft worker* and *hired help*, in the secondary schools of the 1960s, to *subject specialist* in the 1970s, 1980s and 1990s. This subject-centred role was challenged in the learner-conscious knowledge-society of this century and enlarged to include a multiplicity of roles, responsibilities and relationships for the teacher as professional within a newly formed Teaching Council. Following the *Teaching Council Act* 2001, the Teaching Council was launched in February 2005 with start-up funding of Euro 800,000.²¹³ It replaced the Registration Council, founded in 1914, and aimed to self-regulate the profession, to promote the teacher as a professional and the *continuing professional development* (CPD) of teachers in a knowledge society.^{214,215}

From 1960-2005 a number of reports, official documents and pieces of legislation tracked the progression of this changing conception of teaching. The 1984 *Report of the Inservice Committee* of the Department of Education suggested a need for a comprehensive policy on teacher inservice education with an implementation structure working in tandem with Teachers' Centres, subject associations and third-level institutions.²¹⁶ The OECD *Country Report for Ireland* 1991 noted that teaching attracted a high calibre person but pointed out that teaching methods were largely didactic and there was a need for a national investment in inservice training.²¹⁷ This theme was taken up in *The Green Paper, Education for a Changing World*, 1992 the *National Education Convention Report* 1993 and further developed in *The White Paper, Charting Our Education Future* 1995.²¹⁸⁻²²⁰

The role of the teacher was finally put on a statutory basis with the publication of *The Education Act* 1998.²²¹ A multiplicity of teaching roles was also expressed in the review of post-primary teacher education conducted by the *Advisory Board on Post-Primary Teacher Education* 2002.²²² The Teaching Council called for reconceptualising the role of the teacher as a professional practitioner:

from being a craft whose skills could be acquired through apprenticeship and/or a short training course, teaching has come to be regarded as a form of continuing professional development through initial education, induction and incareer development.²²³

The multiplicity of roles the teacher was expected to assume was considerable:

as skilled practitioner in the science and art of teaching, who applies professional knowledge, personal intuition, creativity, and improvisation to accomplishing teaching's tasks; as problem-solving and decision-making clinician; as curriculum maker, researcher, evaluator, and reflective practitioner; and finally, as "significant other person" who exercises considerable moral influence.²²⁴

Sugrue (2002), using the model for teacher specialist knowledge developed by Cochran

Smith and Lytle (1999), noted the discrepancy between these descriptions of the teacher as professional and the reality of Irish teachers experience of professional development and opportunities for professional learning.²²⁵ His research noted that there were no intermediary structures in Ireland between the Ministry and schools and that curriculum days organised for teachers as part of subject matter reforms were provider driven, voluntary, ad-hoc, often fragmented and merely consisted of teachers sharing craft knowledge with other teachers.²²⁶ In the early years of this century curriculum reforms called on teachers to transform their professional practices:

teachers are increasingly being asked to reinvent themselves, to become facilitators of learning rather than repositories of cultural wisdom to be transmitted to their pupils and students.²²⁷

Sugrue (2002) asserted that to connect teacher learning to new pedagogical approaches required a more dialogical and sustained effort than the more traditionally offered *curriculum days*:

without support and feedback for teachers at the level of the school when new methods are being "tried", the pedagogical status quo is likely to prevail.....to improve the quality of teaching and learning, then a more sustained and supportive approach seems vital as well as the necessity in the setting to generate research evidence that seeks to connect teacher and student learning.²²⁸

active participation and dialogue that respects participants' expertise, in addition to support and constructive feedback are vital ingredients in the difficult and complex process of changing pedagogical repertoires and classroom routines.²²⁹

The need to recruit, retain and develop a quality teaching force became the subject of the OECD *Background Country Report for Ireland* in 2003 and was further explored in the OECD report *Teachers Matter* 2005.^{230,231}

Tracking the funding allocated for in-career teachers state-mandated support showed the modest nature of state support practicing teachers had until the mid 1990s. State funding for inservice courses for post-primary teachers in Ireland varied from £203 in 1959/60, to £38,193 by 1979/80.^{232,233} In 1981 only one hundredth of one percent of the total education budget was used for inservice education. This percentage was to change over time, by 1984/85 it had climbed to £1,229,878, while by 2004 this had become Euro 28 million (Table 1.20).²³⁴

From the nineteen eighties onward an increasing number of teachers continued the scholarship of teaching through taking Masters in Education programmes at university, and for this they received a modest increase in salary.

Table 4.9 Government expenditure on teacher inservice education 1960-2005.

Year ending	Currency	Expenditure on Inservice Education
1960	£	203
1965	£	6,961
1970	£	36,423*
1975	£	86,477
1980	£	38,193
1985	£	1,229,878
1997	Euro	10.8 million**
1999	Euro	19.0 million
2000	Euro	25.79 million
2003	Euro	28.68 million

* Both secondary and vocational teachers, 1970 – 1985.

** TES budget.

4.7.1 Post-Primary Teachers – Number, Type, Age and Qualification

Between 1960 and 2005 the post-primary fulltime teaching workforce had increased sevenfold from 3,000 to over 21,000 teachers. In 2003/04 there were 21,414 full-time post-primary teachers of which 60% were female and 40% were male (Table 1.2).

Table 4.10 Number of post-primary teachers 1960-2005.

Year Ending	Secondary	Vocational	Comprehensive	Community	Total
1960	3,150	-	-	-	3,150
1965	4,012	-	-	-	4,012
1970	5,859	909	72	-	6,840
1975	9,431	4,069	402	443	14,345
1980	11,470	4,633	507	1,041	17,651
1985	11,902	4,949	536	1,640	19,027
1990	11,630	4,825	507	1,786	18,748
1995	12,635	5,186	536	2,283	20,640
2000	12,418	5,627	473	2,585	21,103
2005	-	-	-	-	25,609

The bulk of teachers had been employed in the early nineteen seventies so that, by 2005, Ireland had an ageing teaching force.

Post-primary teachers were represented by two teacher unions, the *Association of Secondary Teachers of Ireland* (ASTI) and the *Teachers Union of Ireland* (TUI).^{235, 236}

Both unions were represented as significant stakeholders in all curriculum committees and had grown to a position of strength by the early years of this century. In 2001 teachers had a starting salary of Euro 23,000 which progressed to Euro 28,000 after fifteen years and Euro 45,000 at retirement. These were all above OECD averages of Euro 21,000, Euro 25,000 and Euro 35,000 respectively.²³⁷

4.7.2 Inservice Education and Opportunities for Continuing Professional Learning

Common inservice courses were first offered to secondary and vocational teachers in the late nineteen sixties coinciding with the introduction of a common curriculum in post-primary schools.^{238, 239} A number of significant changes were introduced in the early nineteen seventies including a scheme to reimburse teachers who attended inservice courses and the establishment of a network of Teachers' Centres.^{240, 241} A new junior cycle curriculum (lower secondary) was introduced and accompanied by state-mandated inservice training in 1989.²⁴² This was the first national INSET model, inservice education

and training, delivered by practicing teachers on temporary release from their schools. Inservice education in the nineteen nineties and early years of this century is best understood through three major developments. These developments were concerned with the infrastructure for inservice and the changing nature of the models of inservice support. Firstly, a new *In-Career Development Unit* (ICDU), was established within the Department of Education in 1994 with responsibility for inservice education.²⁴³ The unit was to become responsible for both initial, induction and incareer teacher education, in both primary and post-primary education systems, and renamed the *Teacher Education Section* (TES) in 2004.²⁴⁴ Secondly, the network of teachers' centres was rebuilt as modern state-of-the-art education centres during the nineteen nineties, when £10 million was secured from the *European Regional Development Fund*.²⁴⁵ Thirdly, the older model of inservice education as once off events, half-day or full-day courses was changed.

The newer model of inservice support started with the *Transition Year Support Team* (TYST) in 1995. This was made possible through a budget of £34 million received (1994-1999) from the Human Resource Operations Programme of the European Union, under the *National Development Plan*.²⁴⁶ The TYST consisted of fourteen teachers on secondment from their schools and attached to the Blackrock Education Centre.²⁴⁷ The support service, an outreach of the ICDU unit, was overseen by a National Steering Committee chaired by a senior DES Inspector. The service was regionalised and offered school visits, regional coordinator meetings and liaison with local educational agencies. This model of inservice support was extended to other programme and subject reforms in senior cycle. The DES envisioned a three to four year need for an intensive phase of implementation: *to support specific areas of curricular change and usually for a defined period*.²⁴⁸

When the first intensive phase was completed the DES downsized the team to a diminished service under a generic *Second Level Support Service* (SLSS) which became

operational in January 2001.²⁴⁹ The DES termed this service a *post-implementation* service.²⁵⁰ Senior cycle science inservice education moved, over a three to four year period, from full-time support services, with up to thirty teachers on secondment, to a diminished service with three national Coordinators and one Regional Development Officer (RDO) within the SLSS support service. A support service for physics and chemistry, the physical sciences initiative (PSI-initiative) was first administered by the Limerick Education Centre at a cost of Euro 14 million.²⁵¹ It ran for a four-year period, and was delivered by 16 RDOs under supervision of the DES inspectorate.²⁵² Approximately 1000 physics teachers and 900 chemistry teachers availed of the service.²⁵³ The biology support service started with 12 RDOs in 2001 and provided support for approximately 1700 biology teachers.²⁵⁴ After completion of the first intensive phase of inservice physics and chemistry support the DES considered that *these programmes are well established and will continue to be supported through a single integrated service.*²⁵⁵

In the first year physical science teachers had availed of two and a half days of inservice support.²⁵⁶ They were informed of changes in the new syllabus and how they might apply STS approaches to the teaching of topics. By the autumn of 2005 a starter pack of resources, a web-site and a total of eight newsletters and magazines had been produced.^{257,258} Physics network meetings were organised in the regions through a partnership approach with the ISTA, Institute of Physics (IOP) and Directors of the local education centres in response to local needs. A similar package of support was offered through the chemistry support service.

The national biology support service was established in January 2001, under the auspices of the ICDU and administered by the Tralee Education Centre.²⁵⁹ The service, the *National Biology Support Service* had a national coordinator and eleven RDO's. They delivered inservice support to biology teachers, over 1,400 out of a total of 1,800, in a

number of national venues over a three year period, and were responsible for publication of a web-site and a number of resources. After three years the teachers were returned to their schools and a new service, the Biology Support Service was set up, for three months, with six full time Associates, one Co-ordinator and one RDO. This new service entered an experimental phase in an attempt to link curriculum implementation with the continuing professional development of teachers.²⁶⁰ It was successful, through *teacher design teams* using a university partnership approach, in catalysing over one hundred teachers to produce eighteen resources for the teaching of biology which were shared nationally with other biology teachers.²⁶¹

Between 1960 and 2005 there was no full-time support service for senior cycle mathematics teachers. Syllabus changes in senior cycle mathematics had fallen outside the period of support services, being prior to 1995. In practice this meant that many senior cycle mathematics teachers did not receive any guidance on curriculum development, resource development or new teaching and learning supports, unless they voluntarily attended their subject association or attended inservice development for mathematics reforms in lower secondary education.

The narrow focus of teachers, witnessed by the OECD in 1991, where teachers were mostly purveyors of facts and coaches for examinations, was further entrenched by the rigidity associated with the organisation of teaching and learning in schools:

The single, homogeneous class and the instructional models associated with it are not conducive to co-operative team work or to innovative approaches to teaching and learning.²⁶²

The SDPI team reported in their Annual Report 2002 that schools were not identifying teaching and learning as a central concern:

The organisational areas addressed most frequently on planning days suggest that schools were evaluating organisational issues in the light of their compliance with legal or departmental requirements, rather than their impact on teaching and learning.²⁶³

In 2002 the SDPI grant aided 393 post-primary schools, in excess of Euro 630,000 in total, for their development planning days, at a rate of between Euro 1,270 and Euro 1,905 per school.²⁶⁴ It indicated that, on average, each school had taken one school development planning day in that year. Mc Dermott and Richardson (2005), as part of their work with the second level support service, researched a model of appreciative enquiry on teaching and learning in one post-primary school.²⁶⁵ They reported the reluctance of teachers to go public on teaching and learning, to need for ongoing dialogue in this regard and broadening the narrow base which was overly focused on *rules, routines and administration*.²⁶⁶ Lack of opportunity to engage in dialogue on teaching and learning was identified as a system fault-line:

We do not think it is an exaggeration to state that teaching and learning are rarely spoken about in a public way in schools and remain largely invisible. And, as long as this remains the case, a school's ability to cope with change will be diminished.²⁶⁷

4.8 Future Concerns in Irish Senior Cycle Science and Mathematics Education

By 2005 the school was regarded as the site of educational change yet there were few structural reforms in school organization in the forty five year period of this study. Teachers were increasingly expected to plan collaboratively and regularly evaluate and this was supported by the Teaching Council's recognition of the teacher as professional, and the ongoing work of the WSE and SDPI. The SDPI continued to work with schools to assist development planning and began to offer templates on curriculum planning and suggested that schools might set up subject departments and have subject co-ordinators.²⁶⁸

Another national review of senior cycle was undertaken by the NCCA 2002-2004 in consultation with a wide variety of stakeholders.²⁶⁹⁻²⁷² It set out a vision for the type of senior cycle that might exist by 2010 and initial advice was sent to the Minister for Education for consideration in June 2004.²⁷³ The final report suggested keeping senior

cycle as a two year or three year experience.²⁷⁴ The re-structured curriculum would consist of transition units (45 hour), short courses (90 hour) and subjects (180 hour).²⁷⁵ The review suggested a radical culture change from existing inherited practices to a focus on establishing a culture of learning with a new emphasis on a variety of modes of assessment.²⁷⁶ Assessment was to remain a high-stakes centrally driven process, with no involvement of teachers. The Minister was concerned at the cost involved given that *international trends in high stakes examinations are toward external assessment:*

the assessment proposals could incur considerable extra costs, given the proposals to assess subjects more frequently, to widen the scope for assessment of practical/project/portfolio work, to add national assessment for an extensive range of short courses, and to continue to provide largely for a centrally driven externally examined system.²⁷⁷

A new set of serial reforms of senior cycle physics, chemistry and biology was again planned for 2008-2010. Physics was to be modernised in terms of subject content, practical activities to be reviewed and a second assessment component to be introduced.²⁷⁸ The Chemistry review was to take into account changes in chemistry education. The social, economic, environmental and technological aspects of the subjects were to be enhanced and a second assessment component was to be introduced.²⁷⁹ The Biology review was to reflect the ever-increasing profile of modern biology in scientific and technological developments and issues in society.²⁸⁰ The *Strategy for Science, Technology and Innovation Report 2006-2013* highlighted that senior cycle science curricula needed reforming, that further investment was needed in the continuing professional development of teachers and the issue of technical assistance for schools needed to be revisited.²⁸¹

4.9 Chapter Four: Summary

The essence of the evidence from this chapter is distilled in this summary and dealt with under the heading of the five questions driving the macro-study.

Q1. What are the key features of the national policy process?

There is evidence in this part of the thesis that the macro education policy process in Ireland is consultative, dialogical and political. The DES acts a key player among a variety of actors and ultimate responsibility rests with the Minister for Education. Ireland developed in the mid to late nineteen nineties a policy position with respect to science education. The ideal of developing a type of hands-on science education was promoted through statements made by the Ministry and a range of structural and pedagogical reforms. This included an array of new initiatives including: science teacher inservice support, guidance with respect to teaching and learning - through the syllabuses, NCCA teacher guidelines and WSE criteria for subject evaluation – and a range of once-off grants to support structural reform in the laboratory (Table 4.11). Despite these initiatives Ireland did not produce a policy document, as a blueprint for the future, on how it hoped to develop the mathematics and science competence of its teaching force. While legislation and a multitude of reports lined government shelves there appeared to be resistance to long term policy planning.

Table 4.11 Once off grants to improve the teaching of science in Ireland 1995-2005.

Grant specification	Grant Amount	Chapter Four Reference Number
Computer & Printer	£2,500 per school	18
Laboratory Equipment	£1,500 per school	19
Upgrade Laboratory	£3,500 per laboratory	22
Physical Science Uptake Grant	Euro 10 per student	24
Datalogging Grant	Euro 10,000 per school	27

Q2. What is the changing shape of school organizational supports and structures in the 1960-2005 time-frame?

Throughout the forty five year period of this study there were no formal structures mandated whereby subjects, such as science and mathematics, could be supported. While there was remuneration for posts of responsibility (A- and B-posts), and from 1998 onwards middle management posts were sanctioned (*Assistant Principals* and *Special Duties Teachers*), the school was under no obligation to designate any of these posts for the promotion of teaching and learning in specific subject areas. Schools were generally resistant to state interference in their internal management decisions. A circular letter from the Ministry in 1995, *Time-in-School Circular Letter M29*, detailing the minimum number of teaching days was met with much resistance and had to be quickly withdrawn. Rosenholtz (1991), among others, argued that the development of the teacher as a learner required a structured role for communication between management and teachers and structured meeting-times.²⁸²

Q3. Outline the key curricular and pedagogical reform waves in science and mathematics education in the 1960-2005 time-frame?

Curriculum reform in science and mathematics in Ireland charts a wave pattern changing approximately every twenty years. There were two reform waves in the physical sciences between 1960 and 2005 and only one in biology. There was twenty seven years of a gap between the biology reforms. There were two main reform waves in higher and ordinary mathematics with an additional reform in 1997 for foundation level. Mathematics continued throughout the entire time-frame to be offered, at higher and ordinary levels, as pure mathematics, decontextualised from real world exemplars. While science started off in the 1960s as pure science the policy documents in the 1980s espoused a new emphasis,

identifying the experimental nature of the subject. Science reforms in senior cycle in the 2000s opted for 70% pure science and 30% related to real world exemplars, through STS.

Pedagogical reforms were also introduced, in the science reforms in the 2000s, to promote learning, through a variety of adapted teaching approaches, and self-directed learning. However there appeared, from this study, to be some lack of clarity between the stated aims of the syllabus and teacher guidelines and the emphasis in examination papers. This according to Fullan (2000) could lead to incongruency and make ownership of the reforms more difficult at the level of the school.²⁸³ There were no changes in the format of assessment of either science or mathematics in the forty five years of this study. All subjects were formally assessed by final written state examinations at the end of the two years of study.

Q4. What is the changing role of the teacher and what opportunities are provided for continuing professional learning in the 1960-2005 time-frame?

The role of the teacher changed over the lifetime of this official document study indicating a change from craft worker to subject specialist to a graduate acting as a professional in the early years of this century. This latter conception is in line with Hargreaves and Goodson's (1996) conception of the teacher as a *post-modern professional*.²⁸⁴ It is also in keeping with the conception of the multiplicity of roles of the teacher espoused by the Teaching Council such as *curriculum maker, evaluator, as skilled practitioner in the science and art of teaching and reflective practitioner*.²⁸⁵ Subject knowledge, in preference to pedagogical praxis, was the focus of the science and mathematics teachers during the timeframe of this study judging from the content of the journal of the voluntary subject associations, IMTA and ISTA. In the early 2000s articles started to focus more on experimental work and datalogging.

This focus was also replicated in the type and duration of inservice support teachers received during the forty five year timeframe. Up until the late nineteen eighties there was a scant track record of inservice education. Teachers received INSET training in 1989 for a limited number of days as part of junior cycle reform. Inservice support for science teachers was not provided again until the changing curricular reforms in the early 2000s. During this period science teachers had access to a regional support service for a three to four year period, with one to two inservice days per year. These models of inservice education suggest that teaching was perceived more as a training and dissemination problem rather than the sustained critical co-enquiry deemed to be required for teaching as a professional praxis recommended, among others, by Sugrue (2002).²⁸⁶

Q5. What are the graduation rates in science and mathematics and the changing number of schools and teachers in the system?

Graduation rates were charted for the sciences and mathematics in the period 1960-2005. Physics and chemistry showed a pattern of uptake over the forty five year period that was surprisingly stable. Less than one in five students took these subjects throughout the entire time-frame. While physics and chemistry were showing 12.8% and 14.7% graduation rates in 1960 respectively, by 2005, with a seven fold increase in student numbers, they were still showing similar graduation rates of 14.6% and 15.9% respectively (Table 4.12). Biology was accepted as a matriculation subject and remained popular as a subject choice for students since it was first examined in 1971. Mathematics had a high uptake pattern and graduation, at higher level, increased from 12% in 1960 to 18.1% in 2001.

Table 4.12 The total number of students completing Leaving Certificate (established) and the numbers completing mathematics, physics, chemistry and biology in 1960, 1995 and 2005 and the percentage of the total cohort.

Year	Total Candidates	Maths	%	Physics	%	Chemistry	%	Biology	%
1960	7,966	7,076	88.8	1,021	12.8	1,178	14.7	3,757	47.1
1995	62,739	54,795	87.3	11,091	17.6	8,462	13.4	31,559	50.3
2005	54,073	46,613	86.2	7,939	14.6	8,633	15.9	25,360	46.8

Chapter Five: *Policy as Text* in Upper Secondary Science and Mathematics in the Kingdom of Norway from 1960 to 2005

Chapter Five analyses official documents as they relate to the three sub-themes of the theoretical framework for the study: pedagogy and assessment, organisational reforms and teaching as a professional praxis. The official document search includes analysis of a range of government publications, syllabuses and parliamentary reports (*Storting Reports*) and a selection of peer reviewed publications. The chapter considers the background and context to the study, the macro policy process, the micro policy process, curriculum reform in science and mathematics and teacher reform.

5.1 Background and Context

The Kingdom of Norway is a wealthy country, on the northern periphery of continental Europe, with a long history of socialist governance, a national commitment to equality of opportunity and a policy reform process that is well established. The population of 4.3 million, is fairly homogenous, with the exception of the Sami minority in the far north of the country and a growing migrant population in the Oslo region.¹ The country is geographically vast, indented with fiords, mountains, islands and numerous scattered rural communities (Appendix VII). A wealthy oil and gas producer Norway's economy rests additionally on services, fishing, the metal industry, forestry and international shipping.² Ninety four per cent of Norwegians are members of the evangelical Lutheran Church and this influence is found in its commitment to the greater good in society.³ A social democratic model of education is a key feature of Scandinavian schooling.⁴

Norway prescribes a national curriculum and has a second assessment component for all science and mathematics subjects. It is the teacher who has responsibility for both components. Only 10% - 20% approximately of students take final state examinations in a

lottery type system that was established to ensure national standards were maintained. By the end of this research period, in 2005, it was spending 63 per cent more per student in upper secondary education compared to the OECD average.⁵ By the early years of this century the Ministry recognised that resources and money were *necessary but not sufficient* and relied on research that indicated that quality of teaching was a key factor in developing a quality education system.⁶ In the early years of this century a new emphasis was placed on progressing Norway as a competitive knowledge economy with a focus on quality and accountability.⁷ It is in this context that science and mathematics education became a national policy concern with falling levels of interest requiring a new policy strategy. It is to this national policy making process that we now turn.

5.2 Macro Policy Process

The corporate model of policy formation, where special interest groups establish a consensus approach to education change, also describes the education policy process in Norway.⁸ It had a publicly owned and decentralised education system. Education was managed across three levels, the level of the Ministry, the county authorities and schools, using a power-sharing arrangement. Legislation and national curriculum guidelines were produced at the level of the Ministry, funding for schools and inservice education was the responsibility of the county education directorate while the school was responsible for drawing up policy plans in addition to taking part in a national system of evaluation and quality assurance.

The education system became the responsibility of the Ministry of Education, founded in 1914 as the *Department of Ecclesiastical and Educational Affairs* with responsibility for schools, church, higher education and culture.⁹ The connection between school and church affairs continued until the later years of the twentieth century when the title of the department changed from the *Ministry of Education, Research and Church Affairs* (1991-

2001) to the *Ministry of Education and Research* from 2002 onwards (MER).¹⁰ During the period of this research study, 1960-2005, there were eighteen different Ministers for Education signifying an approximately similar number of changes of government; with the pendulum swinging back and forth in later years between minority socialist labour party and conservative coalition governments (Appendix VIII).¹¹ In September 2000 a *Norwegian Board of Education* was established with responsibility for primary, lower secondary and upper secondary schools.¹² On the 15 June 2004 it was renamed and given a broader remit as the *Norwegian Directorate for Education and Training*.¹³ It became responsible for monitoring education, implementing laws and regulations, compiling statistics, research and development.

The MER served as key policymaker with reforms accompanied by legislation, guidelines and strategic action plans.¹⁴ Several laws governing upper secondary educational reforms, 1964, 1974, 1994, 1998 with an amendment in 2000, were passed through parliament (*Storting*).¹⁵⁻¹⁸ Education policies were written taking primary, lower secondary and upper secondary as a collective.¹⁹ From the nineteen eighties onwards upper secondary education became the responsibility of the nineteen counties (*fylke*).²⁰ County education authorities were composed of officials and elected representatives including a Director of Education. The education budget was paid to these local county authorities as a lump sum in respect of health, education, social and cultural affairs.²¹ The school itself was owned by local government and run through elected representatives and officials.²²

Findings from a range of international comparative studies, such as PISA and TIMSS, presented a major challenge to the political landscape in Norway. Reports from these studies suggested that it was important to assist teachers in reconceptualising knowledge so that it was learner-centred.²³ An OECD comparative study showed that the percentage

of students leaving upper secondary education with a mathematics, science and technology orientation had declined from 27% in 1994 to 20% in 2003, Figure 5.1.

Figure 5.1 The percentage of graduates from upper secondary education with an mathematics, science and technology orientation decreased in Norway from 1994 to 2003.

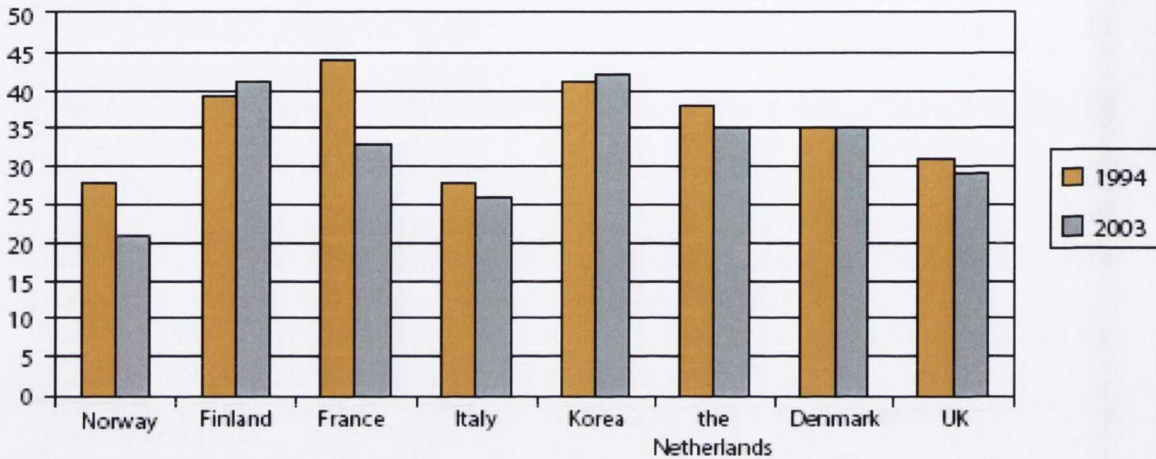


Figure 2: The percentage of graduates from upper secondary education with a MST orientation in 1994 and 2003. (The data for Finland and the Netherlands are from the time period from 1997 to 2003.)

Source: *A Joint Promotion of Mathematics, Science and Technology (MST) Strategy 2006-2009*, (2006), 13, Norwegian Ministry of Education and Research.

In 2002 the Minister for Education, Kristin Clemet, initiated a national strategy for the strengthening of *science, mathematics and technology* through cohering a number of national organisations to improve the status of science and developing a national policy framework.²⁴ A new comprehensive reform policy, *Mathematics, Science and Technology* (2005), was formulated as a national strategy for strengthening science and mathematics from kindergarten through to upper secondary education.²⁵ The strategy recognised a number of policy areas for development including development of MST and teacher competence. Each of these policy areas was further elucidated by goals and initiatives. The C goals were concerned with improving teacher competence, including raising the competence of MST teachers (C1) and increasing salaries for teachers with advanced training in MST (C6).²⁶ Existing teachers were offered an opportunity to continue their academic development through a grant-aided masters' degree programme (C5). A network

of science resource teachers was to be developed through a newly established national science centre, the *Norwegian Centre for Science Education* in Oslo.²⁷ The policy pledged to establish a public arena for science teachers, politicians and business people to have a forum to develop mutual understanding.

5.2.1 Inspection and Quality

From 1960 to 1975 evaluation of schools was by external inspection and regular visits by experts from the Ministry. This system was abolished in 1975 and a newer system of self-evaluation by schools was promoted.²⁸ School-based inspectors assisted the principal in running the school and providing professional support to new teachers:

Previously, departments were strictly related to subjects, containing persons teaching in the same field, for instance science subjects or foreign languages, with one of the teachers being responsible for the work in this department (*hodedlaerer*). A number of so-called *inspectors*, depending on the size of the school, assisted the principal in running the school. They did not have direct subordinates, and all teachers related directly to the principal as to all personnel matters.²⁹

A national strategy for school evaluation and quality development was put through parliament (*Storting*) in the early years of this century. It considered that *adaptation of teaching* for differentiation was the main challenge to ensure that all pupils had an equivalent education.³⁰

Improving *teaching and learning* became the central aim of both national systems of evaluation. The Report to the Storting no. 30 *A Culture for Learning (2003-2004)* concerned students taking more responsibility for their learning.³¹ This reform included the setting up of a national quality assessment system, under the heading *The School Poster* in 2003.³² The *Committee for Quality in Primary and Secondary Education*, formed on 5th October 2001, published its first report on 5th June 2003.³³ Learning was framed in a lifelong perspective.³⁴ This quality system invited students, apprentices, teachers and parents to contribute information about the learning environment in schools through

internet-based questionnaires.³⁵ It became compulsory for all students in grade eleven to reply to this questionnaire, initially called pupil inspectors (*Elevinspektørene*) and later changed to the pupil study (*Elevundersøkelsen*).³⁶ In 2003-2004 there were 50,483 responses from students in the foundation course, indicating a satisfactory rating with the school's physical learning environment.³⁷ It is to this micro level of the policy process, at the site of the school, that we now turn.

5.3 Micro Policy Process

Between 1960 and 2005 all schools in Norway were publicly owned and co-educational with the exception of a small percentage of private schools. By 2003-2004 the number of private schools was 13%.³⁸ Changes in management are considered, in this section, through developments that took place before and after the two major upper secondary curriculum reforms, Reform-74 and Reform-94, in 1974 and 1994 respectively.

5.3.1 Number and Type of Upper Secondary Schools

In the 1960s upper secondary schools were two distinct types: the academic school (*gymnasium*) and the vocational school (*yrkesskole*).³⁹ There were at that time approximately thirteen gymnasium schools and over four hundred vocational schools at the start of this period.⁴⁰ In the reform of 1974 a new type of school was introduced where academic and vocational tracks became housed together in a new type of comprehensive upper secondary school, *videregående skole*.⁴¹ After Reform-74, academic schools, vocational schools and the new comprehensive model, *videregående skole*, co-existed while the overall number of upper secondary schools began to decrease from a high of over 1,000 schools in 1980 to 454 schools by 2005 (Table 5.1).⁴² Of the 454 upper secondary schools in 2005, 376 were owned and managed by the county education directorates, 74 schools were independent and privately owned and 4 were directly owned and managed by the state.⁴³

Table 5.1: Number of upper secondary schools between 1960 and 2005.

Year Ending	Number of Upper Secondary Schools
1967	995
1970	983
1980	1002
1990	842
1995	746
2001	696
2005	454

5.3.2 Management of Upper Secondary Schools

In the 1960s the principal was perceived more as an excellent teacher than manager:

He – female principals were rare – was a *primus inter pares* among the teachers and was relying on personal authority in his role as head of the school. He most probably would not see himself as a manager. The principal usually was a person of high academic standing, and his main task was to see to it that the school functioned as an economic-administrative system.⁴⁴

This was to change and in the management conscious 70s and 80s the managerial role of the school principal came more to the fore. The *Education Act of 21st June 1974* concerning upper secondary superseded the previous act of 12th July 1964 No. 2 concerning education and laid down regulations with regard to the board of management structure within upper secondary schools.⁴⁵ The school management board called the school council, *skoleutvalg* later known as the *driftsrådet*, oversaw the activities of the school and consisted of seven members, two elected by the county school board, two by the teachers’ council, two by the students’ council and one by the council for other employees at the school.⁴⁶

After R-94 the flat organizational structure within schools changed with the introduction, through national agreement, of a middle management tier of Heads of Department (HoD). These heads of department were given considerably reduced teaching hours, 30% teaching and 70% administration, an increase in salary and additional privileges.⁴⁷⁻⁴⁹ The school principal now had the support of three or four heads of department, in addition to a deputy

principal, to assist with the management and organisation of the school on a day-to-day basis. The school principal became more focused on external liaison:

the principal is no longer directly accessible for the teachers. Traditionally, a teacher would seek the principal when in need of talking to someone about professional or personal matters, but now there is in his place the HoD, a colleague as much as a superior. Of course, this person may turn out to be just as able and perhaps even better at communicating, but there is a question of context and culture. A school has always been egalitarian...the teachers have looked upon themselves as a group of equals, and the principal has been *primus inter pares* – *the first among equals*.⁵⁰

The role of the school principal evolved from 1994 to 2005 to become managerial, political and pedagogical (Figure 5.2). This model recognised the pedagogical role of promoting a learning school through leadership. However, management's collective focus on administration often left a vacuum in terms of educational leadership:

The introduction of *professional management* seems to be accompanied quite uniformly in the Scandinavian schools by a feeling that *pedagogical leadership* is suffering. The principal and his or her management team seem to concentrate on other aspects of management, and do not find as much time as deemed necessary to care for what takes place in the class rooms or to cater for the professional development of the teachers.⁵¹

The complexity of the school as an organization was clarified by Nylehn and Presthus (2001) who suggested it had features of a system within a system, a system of professionals working within a bureaucratic system:

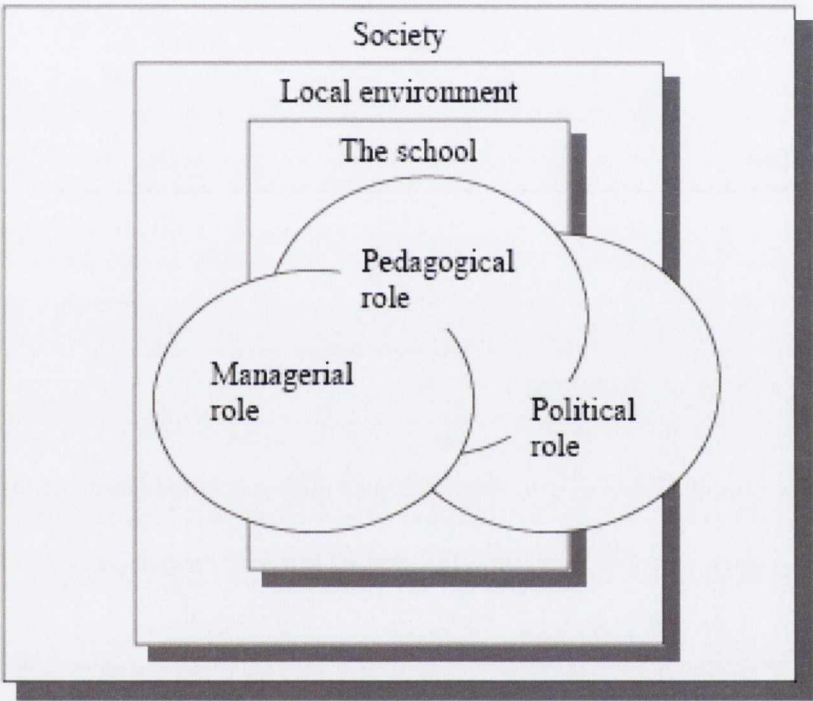
certain aspects of the school organization...are non-bureaucratic or even in conflict with such a model..what goes on in the classes, the teaching and learning processes, cannot be characterized as bureaucracyteachers may be considered as a pool of professionals from which the various classes are supplied with the competent persons they need. This is definitely not a bureaucratic way of organizing, and such a system may be classified as a project or matrix organization. This means that the two school organizations function as manifestations of two quite different types of organizations.⁵²

By the time of the OECD report in 1990 there was a changing conception of the school. It was now considered as a flexible unit for the academic and social development of young people in a changing world. This posed a central challenge to teachers as professionals:

Given the perceptions of their status, teachers will find it more difficult to move from a limited perspective of their role, construed in terms of neatly parcelled proportions of a school day, toward a more generous and fully professional approach which often disregards the boundaries of set time limits and centrally prescribed curricula. It was not easy for us to see how to break this vicious circle and we are aware that its further discussion would lead us to difficult and contested terrain.⁵³

The upper secondary curriculum offered a diverse range of pathways. It is to these that we now turn.

Figure 5.2 The roles of the school principal in the upper secondary school.



Source: Nylehn Borre Av and Presthus, Anne Marie, 2001. *Upper Secondary School Organisations A case study of two Norwegian schools*, 82, Agder University College.

5.4 Curriculum & Pedagogical Reform in Upper Secondary Education

Similar to the senior cycle design in Ireland upper secondary education in Norway was developed for students to enter the world of work or matriculate to higher levels of education. The national curriculum guidelines were sub-divided into values and attitudes and courses of study, with subjects described by objectives and learning targets.⁵⁴ There were many changes in the shape of the curriculum from 1960 to 2005 and these were

influenced by two major curriculum waves, Reform-74 and Reform-94. The upper secondary academic cycle in the 1960s shows a two year cycle (Figure 5.3) while by the early years of this century the cycle had been extended to three years, there were far more courses of study on offer and more flexible pathways between academic and vocational routes (Figure 5.4). In addition the main changes in the early years of this century were underpinned by statutory obligation:

- The cycle was changed from two years durations to three years for academic studies and extending to a possible four years for vocational studies, with the latter often including a two year work experience placement.
- Reform-94 and the *Education Act* (1998), section 3-1, gave a statutory right to all young people, age 16 to 19 years old, to follow upper secondary education over the full three year cycle. Whether they chose to exercise this right was seen as their personal prerogative.^{55,56}
- Students choose between academic and vocational lines of study, and there was an opportunity for any student choosing a vocational pathway to return to academic studies through a number of catch-up courses.
- Teachers were mandated to use a new form of teaching and learning, termed *adapted teaching*, which under section 1-2 of the *Education Act*, required that they adapt their teaching not only for the subject and field of study but for the age and developmental level of each individual pupil and the whole class.
- In section 3-4 of the *Education Act* 1998 detailed the curricular content, pedagogy and assessment reforms in upper secondary education. The Ministry issued regulations concerning the provision of courses, the tuition hours, the subject syllabuses providing *the content of the tuition and how it shall be conducted*.⁵⁷

Reform-94 focused on pedagogical reform. The new emphasis was on co-operative learning, differentiated tailor-made teaching to suit the needs of each individual learner with the teacher serving as planning partner giving guidance and support. This challenge would be strongly felt among science and mathematics teachers who, with their strong discipline background, had a long history of using teacher-guided instruction as the dominant mode of teaching.⁵⁸ *Adapted teaching* required new dispositions, including pre-preparation for the classroom experience and a more reflective approach in post-lesson appraisal, and the development of professional judgments capacities:

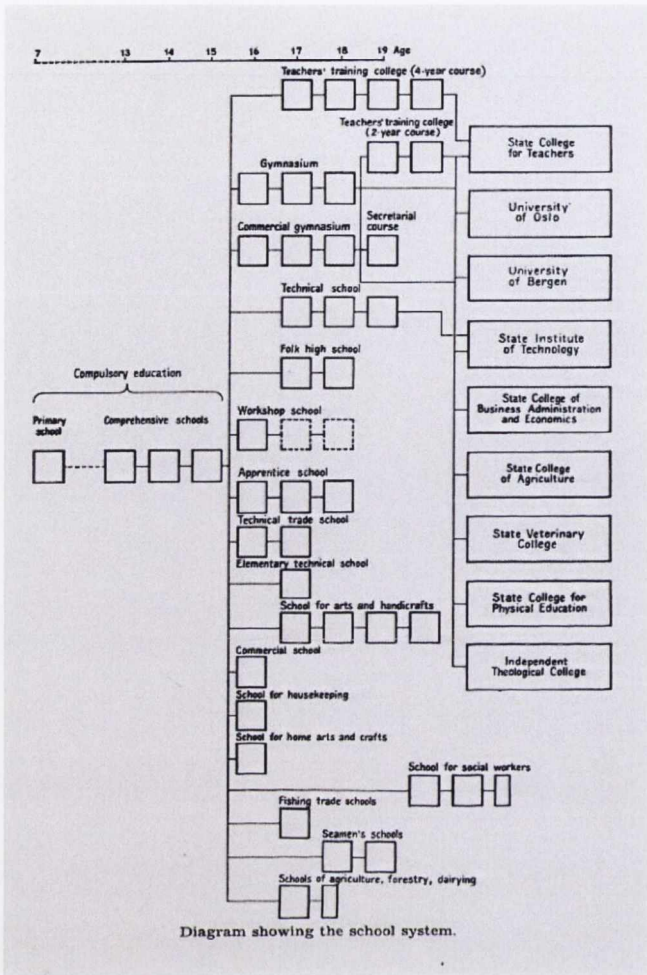
Characteristics of adapted teaching for each and every pupil is variation in the use of subject fields, ways of working and teaching aids and variation in the organisation and intensity of instruction. The pupils have different points of departure, use different learning strategies and varying progression in relation to nationally stipulated competence aims. There are no simple solutions for how to adapt the teaching, it depends on the situation and must be considered in view of the context in which the learning is to take place.⁵⁹

The three year upper secondary cycle was divided into a first year with a common curriculum for all students, foundation year, followed by two years of subject specialisation in a wide variety of courses of study. By 2005 students had fifteen courses of study with over 400 syllabuses to choose from. This section considers the main reforms through the three distinct eras: changes in the 1960s, changes after Reform-74 and after Reform-1994.

5.4.1 Upper Secondary Curriculum and Pedagogical Reform from 1960 to 1974

In the 1960s approximately twenty per cent of students attended the academic school (*gymnasium*) where they received a liberal classical education based on English, Science, Economics and the Classics. There were various lines studied, among them being the *real linje* (mathematics and physics) and the *naturfag linje* (chemistry and biology).

Figure 5.3 The education system in the nineteen sixties.

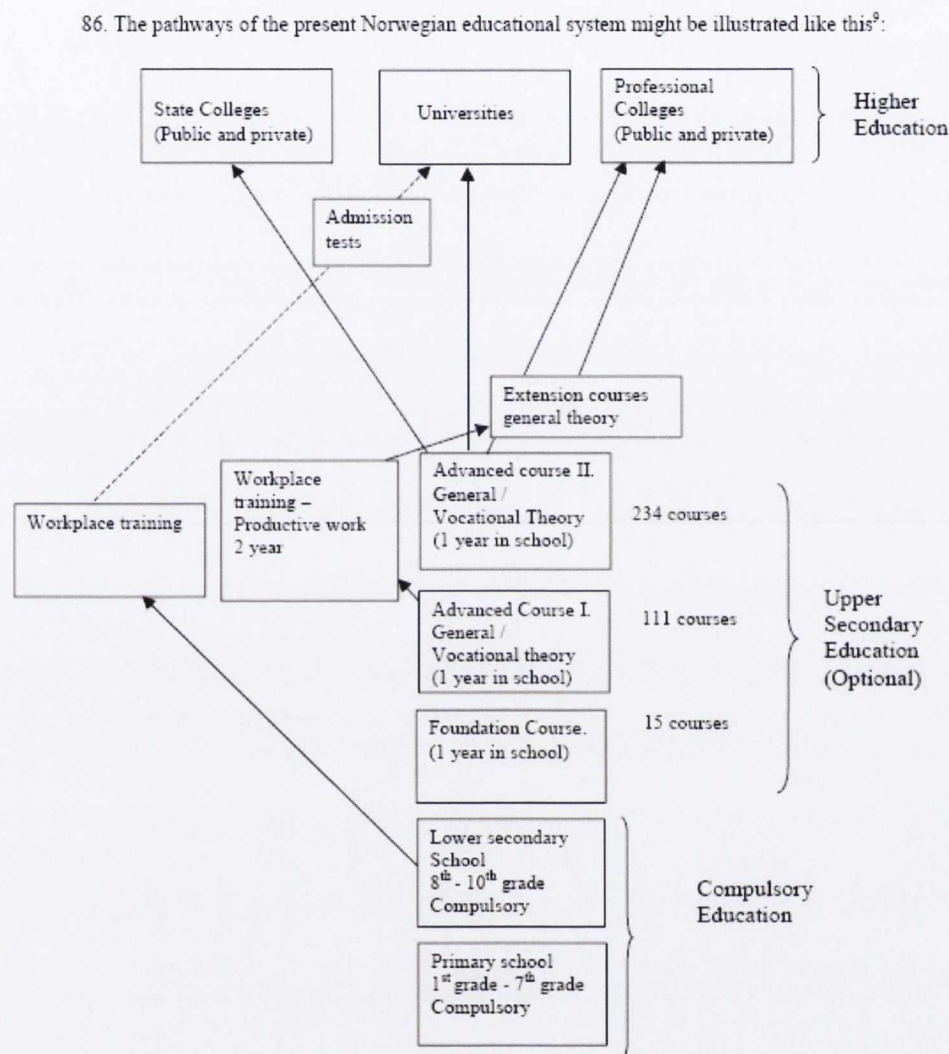


Source: Hove, Olav. (1968) *The System of Education in Norway*, 8, Royal Norwegian Ministry of Church and Education, Oslo.

Students sat a final examination, *examen artium*, set by the *State Council for Secondary Education (Gymnasrådet)*.⁶⁰ A pass in the *examen artium* was required before a student could attend university. By 1960 only twelve per cent of students passed this examination.⁶¹ Graduation rates for the *examen artium* in 1967-1969 are found in Table 5.2.^{62,63} In 1980 the *examen artium* was replaced by general upper secondary education certificates of completion.⁶⁴ The *Steen Committee* of 1965 began a review of upper secondary education and advocated a common system of schooling for all students in the 16 to 19 year age group.⁶⁵ It suggested that this should follow a three year cycle, with a

basic general foundation programme in the first year, followed by a two year programme with increasing levels of specialisation.

Figure 5.4 The education system after Reform-1994.



Source: Lyng, S. T., and Blichfeldt, J.F. 2003, *Attracting, Developing and Retaining Effective Teachers, Country Background Report for Norway*, OECD, March 2003, 25, Paris.

Table 5.2 *Examen Artium* – graduation from the gymnasium 1967-69.

Year	Total	Male	Female	Real-Linje science	Englesk-Linje Modern Languages	Latin-Linje Latin	Norron-Linje Norse	Naturfag-Linje Natural Science	Okonomisk Gymnas Economics
1967	12939	7440	5499	5240	5205	398	62	583	1451
1968	13010	7356	5654	5164	5431	342	88	640	1345
1969	13211	7421	5790	5074	5534	362	97	676	1468

5.4.2 Upper Secondary Curriculum and Pedagogical Reform 1974 to 1993

Upper secondary academic and vocational education became unified in the reform of 1974 (Reform-74) when both school systems were offered together in a new type of school, the *videregående skole*. The new school was sanctioned by the *Upper Secondary School Law* passed in June 1974 to take effect from January 1976.⁶⁶ Students could choose ten different areas of study with one hundred and thirty courses available in vocational lines.⁶⁷ The general studies course, *allmenne fag*, the focus of this research study, was divided into three lines(*linjefag*): languages, natural sciences and social studies, Table 5.3.⁶⁸

Table 5.3 Subjects in the three main lines (*linjefag*) in the general studies course.

Natural Science	Social Science	Languages
Physics	Social Sciences	Linguistics
Chemistry	Social Economics	“A” language
Biology	Business Economics	“B” language
Mathematics	Law	“C” language
	History	Latin
	Mathematics	Old Norse/Icelandic

5.4.3 Assessment

In 1972, a national committee was appointed to examine the assessment system.⁶⁹ A majority opted for abolition of formal examinations in the compulsory school. In the upper secondary schools marks were tolerated but centrally set external examinations were drastically reduced and the main assessment instrument became the teachers’ continuous assessment over the school year. Some random centrally-set examination papers for approximately 10% - 20% of the student cohort and objective marking by external examiners helped to retain national standards. The marking system, prescribed in 1985, had a seven-point scale from six to zero where 3-4 indicated average performance, 5-6 was above average and 1-2 was below average. While 0 was introduced to indicate no goal achievement was attained it was not to be considered as a mark.⁷⁰ Teachers were therefore involved as assessors in the education system in Norway and assumed both a professional

judgment role as well as an advisory role with their students. A comprehensive upper secondary education system, giving equal status to practical and theoretical subjects with multiple tracks all leading to higher education was being realised.⁷¹ Schools showed their progressivism by opting to become multi-line rather than one-line, offering a range of academic and vocational areas of study.⁷² By 1992 more than 80% of upper secondary schools offered more than one area of study with 47.5% offering four areas or more.⁷³

5.4.4 Upper Secondary Curriculum and Pedagogical Reform 1994 to 2005

Reform in August 1994, *Reform-94*, developed upper secondary education as a comprehensive curriculum with an increased variety of flexible pathways between vocational and academic studies.⁷⁴ While earlier curricular reforms focused on structural changes Reform-94 focused on changes in rights and pedagogical reforms. These pedagogical reforms were focused on quality *teaching and learning* and a renewed system of *assessment* for professional praxis. National curriculum guidelines were developed and syllabuses were rewritten.⁷⁵ All subjects had a subject code consisting of two letters and four numbers. Various versions of subjects and their subject codes are given in Table 5.4 for a number of science and mathematics electives in upper secondary education, FY (physics), KJ (chemistry), BI (biology), MX (more theoretically based mathematics) and MZ (more applied mathematics).⁷⁶ The number 2 and number 3 denotes the level of specialization.

Table 5.4 Some science subjects and subject-codes in upper secondary education.

Subject	Subject-Code	Subject-Code
2FY	AA6210	AA6217
2KJ	AA6230	AA6237
2BI	AA6250	AA6257
3KJ	AA6240	AA6247
3MX	AA6520	AA6521
3MZ	AA6544	AA6546

All students in their first year of upper secondary, grade 11, sat a foundation course with some general subjects common to all branches of study: Norwegian, English, Mathematics, Physical Education and Natural Science.⁷⁷ After completing the foundation course, students entered advanced level courses in either academic or vocational education in second and third year, grades 12 and 13. In total fifteen areas of study were approved for upper secondary education in Reform-94: three academic lines and twelve vocational lines, Table 5.5.⁷⁸ Students could achieve matriculation to higher education from the three academic lines of study: *General and Business Studies*, *Music, Drama and Dance Studies* and *Sports and Physical Education*. On 1st March 2004 there were 20, 627 students enrolled in general academic studies out of a total cohort of 61, 847.⁷⁹ There were over thirty five subjects offered in the general studies academic course of study.⁸⁰ Science and mathematics education in the academic *general and business studies* course of study, referred to after 2002 as general studies, management and economics, *allmenne, økonomiske og administrative fag*, was selected as the research area of study for this thesis. Mathematics and natural science were both taught in the foundation year in grade 11. The number of class periods per week for science subjects in the *general studies* course at advanced levels I and II, grade 12 and grade 13, are shown in Table 5.6.⁸¹

Evaluation of Reform-94 was carried out by up to seven teams of researchers, employed by the MER, between 1994 and 1998. At classroom level students were meant to work directly with teachers as planning partners in a movement where students took responsibility for their own learning.⁸² This was reinforced through the publication of a national handbook for students, *The Guide* (1993).⁸³ Monsen's research study (2003) included the voices of over 400 teachers, 30 school principals and 3,000 students.⁸⁴ Monsen (2003) argued that older academic subjects, like mathematics and science, and the

essentialist knowledge conception that teachers' hold ultimately blocked newer conceptions of teaching and learning:

if the intention of teaching is to guide pupils into an almost Platonic knowledge universe of "eternal truths".... What then is the point of having a discussion with pupils about what they are to understand before they have understood what it is all about?....a further development of the teacher's role (and also the pupil's) will require engaging with the teacher's conception of knowledge. This will be a far more demanding task than getting teachers to make compromises.⁸⁵

Monsen's (2003) research showed that 10-20% of teachers became involved in planning with students and worked with colleagues in development planning under the direction of the school principal or a Head of Department. He referred to these schools as learning organisations. Another thirty per cent of teachers tried some planning but this often involved only using *the Guide* at the start of the year. 20-25% of teachers remained deeply sceptical and regarded Reform-94 merely as a bureaucratic exercise.⁸⁶ In some schools where teachers took the initiative, without the support of the school management, their efforts were eventually thwarted by the apathy of their students and the smugness and inertia of their colleagues.⁸⁷ There was a large difference between schools and reform was more successful in schools that were already more familiar with reform! Traditional didactic teaching methods, blackboard teaching and individual assignments dominated the research findings.⁸⁸ Monson (2003) argued that reforms needed to engage teachers' in the reconceptualisation of knowledge:

The traditional teacher role is so strongly welded to an essentialist conception of knowledge that it is quite unlikely that teachers are willing to make further compromises in the direction of a reform, the value of which they doubt. A further development of the teacher's role (and also the pupil's) will require engaging with the teacher's conception of knowledge.⁸⁹

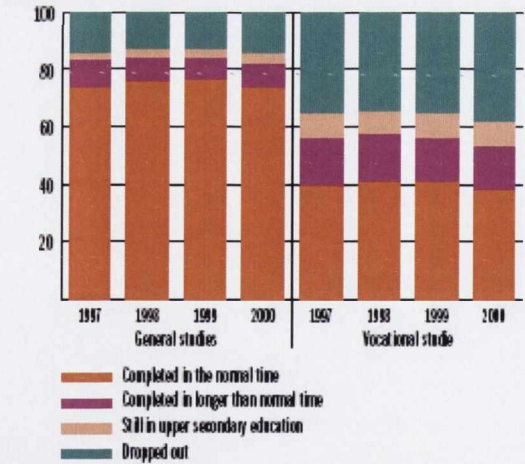
From 1997 to 2000, an average of 74.6% completed general studies within the normal time, a further 8% completed within five years and 14.1% dropped out.⁹⁰ It may be seen in Figure 5.5 that, five years after starting upper secondary school, over seventy percent

completed the academic general studies cycle while only forty per cent completed vocational studies programmes in the same period.

5.5 Curriculum & Pedagogical Reforms in Upper Secondary Science Education

By 2001/2002 only 16.6% of Norwegian upper secondary students choose natural science compared with 30.6% in Sweden.⁹¹ In earlier times, in the nineteen sixties and nineteen seventies, there was a period of experimentation and a pro-science movement in Scandinavian schools.⁹² The number of students taking the science line (real science) increased from 2619 in 1960 to 5576 by 1975 (Table 5.7).⁹³ This golden age of science in Norway lasted from 1950 to 1967, when science subject popularity was steadily increasing, but after that period a downward trend persisted.⁹⁴ The decline, in the early years of this century, was happening at the same time that science and mathematics courses were requirements for higher education studies in medicine, engineering and related disciplines (Table 5.8).⁹⁵

Figure 5.5 Status five years after starting school for pupils in general studies and vocational studies programmes for pupils starting school in 1997, 1998, 1999 and 2000.



Source: Statistics Norway

Source: Utdanningsdirektoratet, 2006, *The Education Mirror An Analysis of primary and lower and upper secondary education in Norway*, 75, The Norwegian Directorate for Education and Training.

Table 5.5 Students and apprentices in upper secondary education, by area of study, 2004.

Area of Study	Total	Per cent females
General Area of Study	89 777	53.9
General, economics and management studies	76 336	53.9
Music, dance and drama	5 476	72.3
Sport and physical education	7 965	41.8
Vocational studies	83 601	48.2
Health and social studies	18 007	89.8
Agriculture, fishing and forestry	4 102	54.6
Arts, crafts and design studies	12 924	85.3
Hotel and food-processing trades	6 848	55.1
Building and construction trades	7 328	1.8
Technical building trades	2 242	9.4
Electrical trades	9 255	3.8
Engineering and mechanical trades	11 886	5.5
Chemical and processing trades	836	29.3
Woodworking trades	608	16.4
Media and communications	4 588	54.9
Sales and service	4 977	58.1

Table 5.6 Number of class periods per week in science subjects chosen in *general studies* at advanced level in upper secondary education.

Subject	Advanced Course I	Advanced Course II
Mathematics	5	5
Physics	5	5
Chemistry	3	5
Biology	3	5

Table 5.7 Uptake of science line from 1960-1975.

Year	Real science
1960	2619
1965	5077
1970	5013
1975	5576

Table 5.8 Higher education studies that require specialisation in mathematics, science and technology electives.

Higher Education study	Electives required
Pharmacy	2MX/2MY/3MZ and 2FY and 2KJ and 3MX/3MY/3BI/3KJ
Aquaculture and fish health	2MX/2MY/3MZ and 2KJ and 2BI/2FY
Medicine, Odontology and Nutrition	2MX/2MY/3MZ and 2FY and 3KJ
Dental Technician	2MX/2MY/3MZ/2FY2KJ
Veterinary	2MX/2MY/3MZ and 3KJ
Economic-administrative education	2MX/2MY/3MZ

The doctoral thesis of Eggen (2004) considered the difficulty of attracting students toward science given the different ideological positions of science teachers: ranging from epistemologically essentialist, to epistemologically progressive and diverse.⁹⁶ Sjøberg and Jorde (1995) explained the weak role of science in the Norwegian education system on the basis that teachers came from liberally educated backgrounds and generally attached less weight to the theoretical.⁹⁷ A child-centred approach was viewed as the opposite, and even in direct conflict with, a subject-centred approach:

An ideological climate has been produced (and reproduced), both among professionals and the public debate, that has been rather alien to academic subjects, especially science and technology.⁹⁸

Science and mathematics education in Norway was described by Fensham (1995) as a modest programme.⁹⁹ The situation did not improve and by 2001 a report by the United Nations, *Making New Technologies Work for Human Development*, indicated a low uptake of *mathematics, science and technology* (MST) by Norwegian students.¹⁰⁰ Sjøberg (2003) suggested that science curricula may be outdated and irrelevant, that there was a rejection within western society of scientific rationality.¹⁰¹ He argued that there was a science war among some postmodern thinkers about the epistemology of science and its personal and contextual relevance:

a white-coated, hardworking and not very well paid scientist in a laboratory is thus not a role model for many of today’s young people. The social climate, especially in developed countries, is not one which it is easy to convince young people that they should concentrate on learning science at school and beyond.¹⁰²

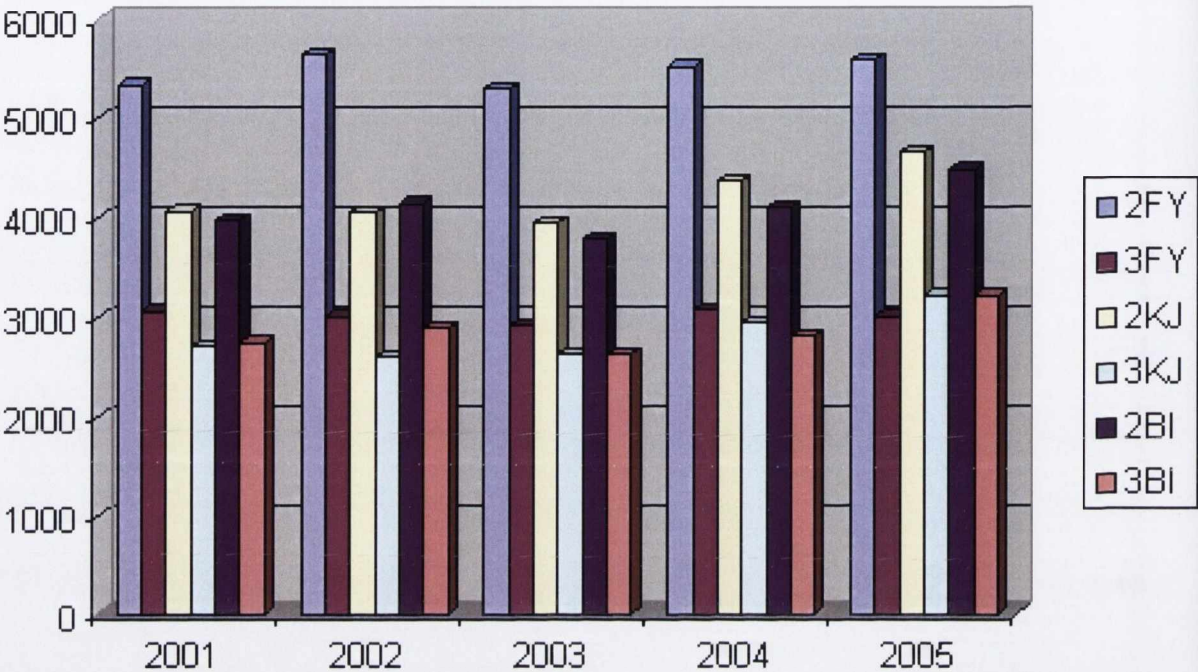
5.5.1 Graduation Rates in Upper Secondary Science Education

The *Norwegian Directorate for Education and Training* gained responsibility in 2004 for compiling national statistics. Data for the number of students who achieved competency in science subjects (passed with at least a grade 2), physics, chemistry and biology, at advanced level I and level II, was certified through the *National Certification Database*, between 2001 and 2005. These are represented graphically in Figure 5.6.^{103,104} This may be contrasted with the number of students who achieved competency and were certified in natural science in foundation year, Figure 5.7.¹⁰⁵ The tables of data from which the graphs are drawn are given in Appendix IX. While a majority of students completed upper secondary education in the three year cycle a significant number completed it in four to five years. There may therefore be a slight discrepancy between the number of students who passed a subject in a given year and the number of students who received certificates of completion. For example, if we consider the attainment of competence in physics in advanced level I, 2FY, by the end of the school year 2004. 6373 students achieved this competence of which 5113 took general subjects in advanced level I, an additional 1045 general studies students achieved it at levels other than advanced level I and 215 students attained competence in 2FY physics through a number of vocational lines of study.

Uptake of science subjects appeared stable and there appeared to be a slight positive trend toward the higher specialization in chemistry and biology (3KJ, 3BI).^{106,107} Science subjects were mostly chosen by students following general lines of study by comparison to a much smaller number following vocational lines of study. Roughly equal numbers took physics, chemistry and biology. There were higher numbers taking physics in advanced level I, 2FY, as this was required for many higher education courses.¹⁰⁸ There was considerable drop-out levels in science subjects between advanced level I and advanced II.

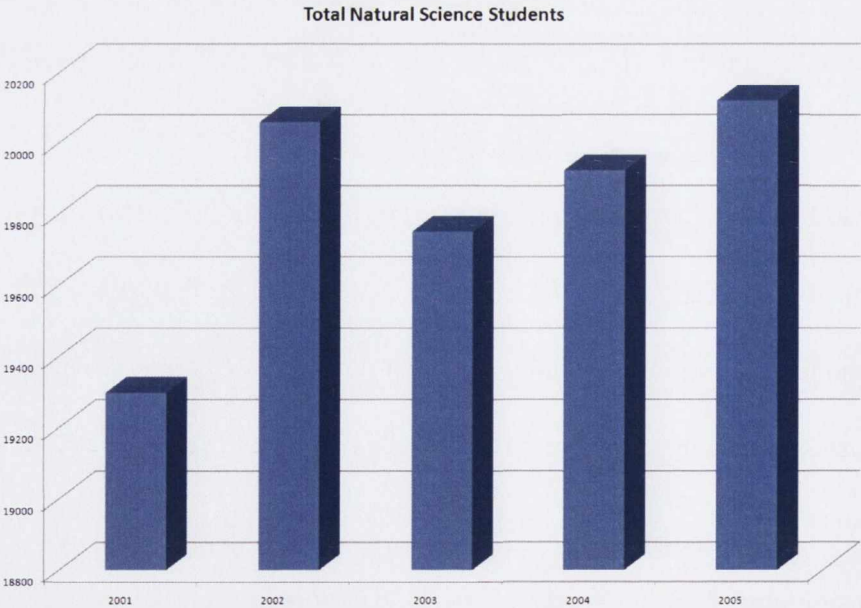
Only half as many students completed 3FY, 3KJ and 3BI as the corresponding subjects 2FY, 2KJ and 2BI.¹⁰⁹

Figure 5.6 Number of students who achieved competency and were certified in physics, chemistry and biology, in advanced level I and II, between 2001-2005.



Source: Compiled by Author from data in Torbjørn Hægeland, Lars J. Kirkebøen and Jens Fredrik Baumgarten Skogstrøm (Upper secondary school competence in science and technology and applications to higher education) Statistics Norway, 41, 2007.

Figure 5.7 Number of students who achieved competency and were certified in natural science in the foundation course of study 2001-2005.



Source: Compiled by Author from data in Torbjørn Hægeland, Lars J. Kirkebøen and Jens Fredrik Baumgarten Skogstrøm (Upper secondary school competence in science and technology and applications to higher education) Statistics Norway, 41, 2007.

5.5.2 Science in Foundation Year of Upper Secondary Education

All students in the first year (grade 11) studied natural science in their foundation course (*grunnkurs*).¹¹⁰ The syllabus, revised in 1994, remained in place for the duration of this research study.¹¹¹ To convey the social significance of the natural sciences, examples were linked to technology, environment and health and offered the possibility for discussion of ethical issues.^{112,113} The syllabus was presented as two class periods per week, 75 hours per year, or as five class periods per week, 187 hours per year. Of the five lessons per week in the academic track, two were allocated to chemistry, two were allocated to biology and one was allocated to physics.¹¹⁴

A number of research and development projects tried to develop learning and higher cognitive skills in the foundation course. The *Open-Book Assessment* (OB) project by the University of Tromsø was one such example.¹¹⁵ The intervention, from 1995 to 1998, involved thirteen teachers and three hundred and fifty students studying the foundation natural science course, in grade 11. The researchers on the project, the science teachers and students' all wrote critical incident reflective journals using an action research approach. The project revealed that science teachers had a strong reliance on the textbook. Eilertsen and Valdermo (2000) argued the value of developing learning and critical reflection through strengthening meta-cognition:

OB (open book learning) has proved to be a fruitful provocation for teachers and students in the teaching and learning of science at the upper secondary level. It has been instrumental in strengthening the awareness and understanding of the nature of knowledge and the process of learning. In learning environments based on collaboration, student participation and a focus on learning strategies and metacognition, OB assessment has made a natural and effective contribution.¹¹⁶

5.5.3 Curriculum and Pedagogical Reform in Science at Advanced Levels I and II

In the second and third year, grade 12 and grade 13, syllabuses (*laereplan for videregående opplæring*) for courses in physics, chemistry and biology, *fysikk, kjemi,*

biologi, at advanced level I and II (VKI and VK2) in the general studies programme (*allmenne, økonomiske og administrative fag*) were reviewed in 1996 for implementation in 1997-1998.¹¹⁷ These were to remain in place until the end of this research study in 2005. In 1998 a scheme was introduced giving extra grade-points to those who chose mathematics and science subjects in upper secondary and was further extended in 2005.¹¹⁸ Syllabuses in physics, chemistry and biology, from the *Ministry of Education and Research* presented a rationale for the subject, objectives and learning targets with an outline of subject content and a rationale for assessment.¹¹⁹

All science and mathematics reforms expected teaching to involve students in experimental and activity based learning, using computer technology where appropriate, while students were expected to take responsibility for their own learning. Teachers were expected to be involved in the grading process and take part in a process of *continuous assessment of their teaching* (self-evaluation).¹²⁰ Reform-94 underpinned the science and mathematics reforms with it's emphasis on self-directed learning and differentiated teaching. The main reforms involved changes in teaching and learning that were learner-centred with the teacher acting as planning partner, guide and mentor. Average achievement grades and central assessment in some selected science subjects are given, Table 5.9, in advanced course II in 2005.¹²¹

Table 5.9 Average overall achievement grades and central assessment grades in selected science and mathematics written examination in Advanced Course II, 2005.

Written Examination 2005	Overall Achievement Grade	Central Assessment
Physics, 3FY	4.0	3.6
Chemistry, 3KJ	4.1	3.6
Biology, 3BI	3.9	3.3
Mathematics, 3MX	4.0	3.5
Mathematics, 3MY	3.6	3.2

5.5.4 Curriculum and Pedagogical Reforms in Physics

The physics course was designed for the enquiring mind and a deeper understanding of the physical world. The physics syllabus, in the general studies programme of upper secondary education, was offered at advanced level I and advanced level II, as two separate programmes 2FY and 3FY, both requiring 187 hours of tuition, roughly 5-hours per week.¹²² Access to physics depended on the student having already taken the five hour natural science and mathematics programmes in their foundation year. Students of physics were expected to study mathematics, or have qualifications already, in the corresponding mathematics courses. Approximately forty per cent of Norwegian students entered the general studies academic strand in upper secondary education and of these twelve per cent opted to take physics as a subject in grade 12 while seven per cent chose physics in grade 13.¹²³ The general physics programme, 2FY, was more qualitative in nature than the more formalised and mathematical course followed in 3FY. Students taking 2FY were introduced to, among others, the concepts and laws of electricity, the properties of light and waves and atomic and nuclear physics. Students of 3FY were introduced to astrophysics, quantum physics and Einstein's relativity theory.

According to the physics syllabus teaching methods were based on experiment and investigation and students were to become responsible for their own learning. Assessment in the syllabus review in 1997 was designed to serve a variety of purposes: to ensure national standards, to inform, to motivate and develop the student, with marks awarded both for classwork and final examination.¹²⁴ This involved the teacher in the grading process and gave students a mark from school and a mark from their external examination. Norway experienced a decline in enrolments in physics courses from grade 12 to grade 13 (the year of graduation).¹²⁵ Students who choose physics were, like their teachers, often quite traditional about teaching strategies and deriving fulfilment from theoretical aspects:

the picture that emerges of Norwegian physics pupils and their teachers is that they represent a closed system where both parties seem to get the subject they want. Pupils appear quite conservative, they are satisfied with the subject and the instruction, and have few wishes for change. The teachers on their side get interested and motivated pupils who are very much like themselves.¹²⁶

The perception that physics was difficult had its' origins in its gatekeeper function to prestigious higher education courses:

should these findings be interpreted to mean that physics is inherently more difficult than other disciplines, or is it the level of school physics – for historical or other reasons – unjustifiably high? Maybe both are the case. Physics has a long tradition of being looked upon as difficult and functions as a gatekeeper to prestigious higher education courses such as medicine and engineering.¹²⁷

Angell et al (2004) argued that the need for school physics underlined a societal need for people who can think deeply and possess curiosity to explore other possibilities:

physics is an ancient science involving everything from basic philosophical questions to everyday phenomena, from nature's smallest building blocks to the most distant galaxies, from high-tech satellites to processes in the human body. Continued recruitment to physics is important – not only to secure scientific expertise and literate citizens, but also because young people deserve to take part in the elegant and intriguing system of thought that physics represents.¹²⁸

A research study of two hundred and thirty six students from twenty different upper secondary schools examining the best ways of introducing quantum mechanics was undertaken by Olsen (2002).¹²⁹ He suggested that there were strong forces for conformity and these made innovative methods more difficult to implement:

Norwegian physics teachers follow a somewhat similar approach because there are some strong driving forces toward conformity in our school system. These forces are a centrally developed and written curriculum, a centrally developed written exam and a very small selection of available textbooks (three different textbooks exist). However there were rather large differences in the instruction in these classes. For instance, the length of instruction time students had received varied greatly from 4 lessons to 20 lessons.¹³¹

5.5.5 Curricular and Pedagogical Reforms in Chemistry

Chemistry was taught in the general studies programme in upper secondary as two separate courses of study, 2KJ and 3KJ at advanced level I and advanced level II.¹³¹ The 3KJ course of study was taken as part of the advanced course II and based on a

continuation study of module 2KJ. The syllabus, updated in 1996, presented a rationale for the study of chemistry:

through a study of chemistry, pupils acquire the knowledge and understanding to explain and predict how substances will behave in the environment and in everyday contexts. They also gain an insight into our dependence on chemistry in manufacturing industries, nutrition, health care and other important areas of their lives.¹³²

Among the objectives and learning targets specified students needed to:

- Be able to carry out experimental work in various areas of the subject and be able to work accurately and safely.
- Know how chemistry was applied in industrial enterprises locally or in the region.
- Discuss ethical issues related to chemical knowledge and its use.
- Be familiar with appropriate means of preventing or reducing chemical pollution.
- Defend their own ideas and give reasons for their choices, and show respect for other people's views regardless of their background, age, sex and religion.
- Take responsibility for their own learning.

Access to chemistry was based on having completed the 5-hour natural science course in foundation year. The 2KJ course involved 112 hours of tuition, the 3KJ course involved 187 hours of tuition, 3-hours and 5-hours per week respectively. Students taking 2KJ were introduced to chemical equilibrium, hydrocarbons and acids and bases while students taking 3KJ studied the nitrogen and phosphorus cycles, analytical methods in inorganic chemistry and material chemistry. In the most advanced course, 3KJ, students were required to become familiar with a number of different reaction types.¹³³

The doctoral thesis of Valdermo (1995), entitled *Whose needs and whose interests are taken care of by the chemical education system in the 6th form college in Norway?* was critical of a lack of philosophy in chemistry education in the upper secondary

curriculum.¹³⁴ Teaching methods were questioned as part of a domino effect arising from this lacuna:

the analysis criticises the didactic approach from what to why in subject curriculum planning and discusses the importance of beginning with the subject's why and wherefore.¹³⁵

The national curriculum was mostly written by well-established chemistry teachers and was designed within limited educational experience.¹³⁶ Valdermo (1995) emphasised the student-subject-society relationship and presented some blue skies thinking for a curriculum more relevant to the needs of students and society. The chemistry curriculum was established in 1970 before the general curriculum was formulated in 1974. The chemistry syllabus was again revised in 1985 and drew critical reaction from universities but this had little effect:

contributions from postgymnasial institutions are too superficial to have any influence on the formation of the curriculum on schools.¹³⁷

Students struggled with understanding the mole concept and mathematical algorithms involved in problem-solving. Most students did not take chemistry beyond 2KJ or 3KJ. The reform in 1997 was far less mathematical and had more industrial applications.

5.5.6 Curricular Reforms in Biology

Biology was offered as a specialist subject, in the general studies area of study, as two separate courses, 2BI and 3BI, at advanced level I and advanced level II respectively.¹³⁸ The biology course was based on the five hour natural science course offered in foundation year. The Ministry (MER) suggested that research on topical issues, such as gene technology, offered an opportunity for debate and drew on other subjects for example, religion and ethics:

developments in gene technology have also provoked a debate on ethical issues, and may, like the environmental problems we are already facing today, raise questions about our unique position in the natural world. In discussion on such matters, it is logical to draw on other subjects as well, such as social studies, Norwegian, and religion and ethics.¹³⁹

According to the biology syllabus students taking 2BI studied a range of topics, including classification, the nervous system and the sense organs while students taking 3BI studied, among others, a natural habitat, the theory of evolution and gene technology.¹⁴⁰ Objectives stated that students should be able to:

- Design their own investigations, process data, and present and evaluate possible sources of error.
- Discuss ethical aspects of biological issues.
- Defend their own ideas and give reasons for their choices, and show respect for other people's views regardless of their background, age, sex or religion.
- Understand how they can act in the best interests of the environment and the importance of conserving biological diversity.
- Take responsibility for their own learning.

Pettersen (2005), in his study of the attitudes to alternative medicine among higher education health science students, argued that the teaching of upper secondary courses in biology, 2BI and 3BI, and the biology component of the integrated natural science foundation course, did not contribute to sufficient scepticism and the capacity of students to think critically and scientifically.¹⁴¹ Both students and teachers reported difficulty in accomplishing all that was required suggesting that the syllabus was more content-led than inquiry driven.¹⁴²

5.5.7 Summary of the Key Features of the Science Reforms

The reforms in physics, chemistry and biology in the late nineteen nineties and early years of this century were strongly focused on the promotion of learning. Differentiated teaching was mandated and this was to be supported in the classroom through a teacher-student planning relationship. Teaching and learning were to provide the student with skills and

qualities that would help develop self-directed learning. In all science syllabuses there was an emphasis on experimental work, on using technologies, on relating science topics to everyday life, on developing capacities to debate ethical issues, on appreciation of the historical development of the subject and understanding principles and concepts. Each syllabus mandated a number of tuition hour per year, 187 hours for physics and advanced chemistry and biology, 3FY, 2FY, 3KJ, 3BI, and 112 hours for chemistry and biology at the first year of specialisation, 2KJ and 2BI. All courses were based on the 5-hour natural science foundation course. Assessment was by continuous and final assessment. Learning targets for assessment of experimental work were listed.¹⁴³ These indicated that pupils shall be able to:

- Carry out experimental work in various areas of the subject.
- Suggest and carry out their own experiments.
- Use various kinds of instruments, including computer equipment, for registration and analysis of measurements.
- Observe and interpret measurements and present them in various ways.
- Evaluate uncertainty and sources of error and carry out simple calculations of uncertainty.
- Be familiar with the risks associated with experimental work.

5.6 Curriculum & Pedagogical Reform in Upper Secondary Mathematics Education

Mathematical test scores for Norway from TIMSS (1995, 2003) and PISA (2000, 2003) were all mid-range.^{144,145} These findings were confirmed by additional research conducted by the *Norwegian Council for Mathematics* which showed a deficiency in basic skills in students entering higher education institutions.¹⁴⁶ Mathematics was sub-divided into two

levels of specialisation, a more theoretically challenging course and a more applied course. Mathematics was only compulsory in 2003-2004 in the first year of upper secondary education. This led to a decline in uptake in mathematics in the final two years of specialisation. This section considers the key changes in mathematics between the 1960s and 1990s, the curriculum and pedagogical reform in mathematics in February 2000, graduation rates in mathematics and the key policy changes introduced in 2005.

5.6.1 Curriculum and Pedagogical Reform in Mathematics 1960-1990

New mathematics was introduced in the 1960s by the Nordic Committee. Extensive criticism voiced in 1972 led to a new syllabus being introduced with Reform-74.¹⁴⁷ All students in general academic studies completed a five-hour per week compulsory programme in mathematics, 1MA, in year one. After this first year students continued with one of two programmes of study, science mathematics (2MN) or social science mathematics (2MS), or decided that they would continue their studies without mathematics. The science mathematics, MN, was theoretically more challenging than the social science mathematics, MS. In their third year of study students continued with further specialization in either theoretical or applied mathematics, 3MN or 3MS respectively. Berge's (1992) research confirmed that fifty per cent of girls dropped out of mathematics studies after the first year and of those that remained less competed for the more theoretical courses.¹⁴⁸ By the early years of the nineteen nineties over 25,000 students began general academic studies but less than 10,000 completed the full three years of mathematics (Table 5.10).¹⁴⁹

Table 5.10 Uptake of mathematics in upper secondary general studies education over the three year period 1989-1991.

Year	Mathematics Programme	Total	Boys	Girls
1988-1989	1MA (compulsory)	25,663	11,529	14,134
1989-1990	2MN science mathematics	10,489	6,198	4,291
	2MS social science mathematics	5,230	2,537	2,693
1990-1991	3MN science mathematics	8,331	5,435	2,896
	3MS social science mathematics	1,580	817	763

5.6.2 Curriculum and Pedagogical Reform in Upper Secondary Mathematics in 2000

The upper secondary mathematics syllabus, published in February, 2000, indicated that it was written from a constructivist and more eclectic learning perspective.¹⁵⁰ It suggested that mathematics was not merely a set of mechanical routines to be mastered and focused attention on the need to involve the student in problem-based and creative learning:

Mathematics is not a collection of “recipes” and algorithms for solving routine tasks, but a toolbox containing the equipment needed to solve problems that require both imagination and understanding. It is important for their attitude to the subject to introduce pupils to this approach as soon as possible, and to give them tasks that are challenging but manageable. When mathematics is used to solve real-life problems, the pupils must be involved in the whole process, from the original problem to formulating it in mathematical terms, solving the mathematical problem and interpreting the answer in real-life terms.¹⁵¹

As part of the objectives and learning targets set for the various courses of study the ability *to discuss and cooperate with others* was explicitly mentioned.¹⁵² Furthermore assessment was considered from the viewpoint of assessment of learning, for maintenance of national standards, and assessment for learning, *to guide, motivate and develop each pupil*.¹⁵³

Mathematics was offered, after foundation year, as a specialised subject divided into the more theoretical X course or the more applied Z course. Among the objectives for all these courses were ability with language and communication, model building and problem-solving. One of the learning targets for language and communication was the need for pupils *to be able to discuss and cooperate with others to solve mathematical problems*.¹⁵⁴

Learning targets for model building and problem solving were listed as:

- Be able to formulate and solve problems that require initiative, imagination and insight.
- Be familiar with and able to choose between various strategies and types of support material for problem-solving.
- Be able to translate problems from real life, the natural sciences, economics and technology into mathematical models.
- Be able to evaluate and test their own models and solutions, interpret the answers and modify their problem-solving strategies.¹⁵⁵

5.6.3 Mathematics in Foundation Year of Upper Secondary Education

The foundation course in mathematics, in grade eleven, included aspects of algebra, graphs and functions including linear functions, quadratics and exponentials.¹⁵⁶ The syllabus argued for mastery of fundamental skills and compared this to the proficiency needed to master a musical instrument:

Mathematics embraces both theory and skills. To master it, one needs not only to understand the theoretical reasoning which binds the subject together, but also to have memorised countless calculating techniques. Understanding and skills are closely interrelated: without understanding, the skills are meaningless manipulations, and without the skills, the understanding has no practical value. A mathematician who needs to stop to think before adding two fractions together is as helpless as a pianist who has to sort out how to strike a chord.¹⁵⁷

without understanding skills are only meaningless manipulation, and without skills, understanding has no practical value (*as well as the need for a mathematics rigour and mental agility in calculation*) practicing calculation techniques is to mathematics what practicing scales is to a pianist.¹⁵⁸

Mathematics was presented in foundation level as three modules: Module 1, Module 2A and Module 2B, the latter two modules later referred to as 1MX and 1MY. All students, both vocational and academic lines, took Module 1 which consisted of 112 periods of mathematics, three periods per week, in the first semester of grade eleven. In the spring semester of grade eleven students, in the academic lines, selected either Module 2A (1MY) or Module 2B (1MX). Module 2A was a 75-hr course, 2 periods a week, suitable for students who wanted a more practically based course. Students who wanted a more theoretical course selected Module 2B (1MX). Completion of this module was a prerequisite for any student proceeding to advanced level theoretical mathematics, 2MX or 3MX, in advanced level I and II. The target areas included exploring mathematics as cultural heritage, the ability to communicate and to explore real life problems.¹⁵⁹

5.6.4 Curricular & Pedagogical Reform at Advanced I and Advanced II

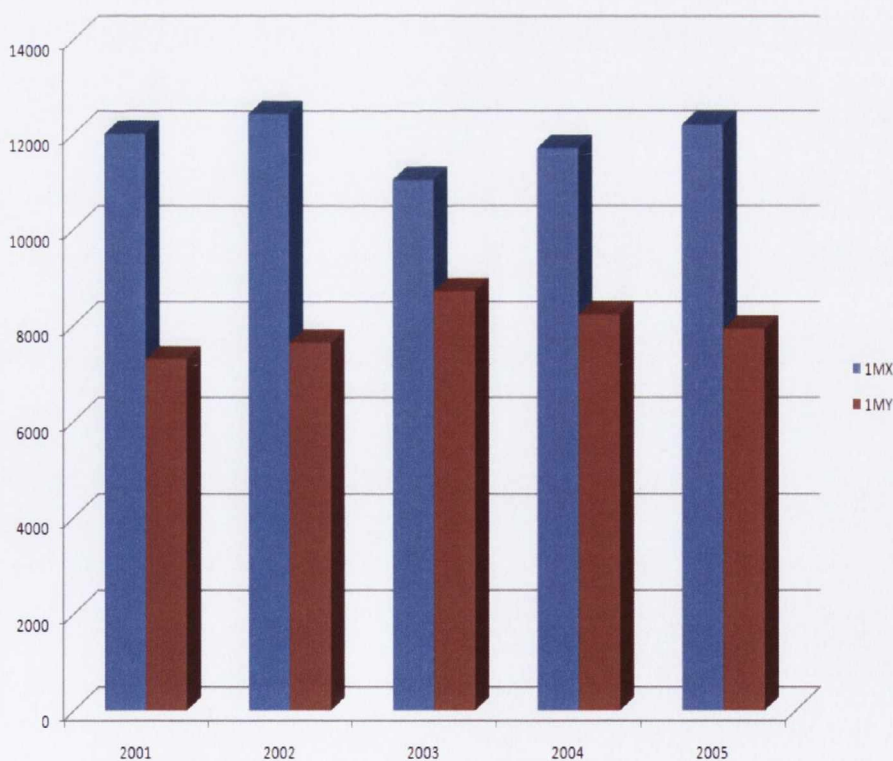
The upper secondary mathematics syllabus was reviewed in 2000.¹⁶⁰ In the academic track students had the option of taking mathematics at advanced level I (mostly in grade 12) and at advanced level II (mostly in grade 13). In grade 12 it was offered as two separate courses of study, 2MX or 2MZ. These varied in their level of specialisation and their emphasis on theoretical or applied mathematics. The 2MZ course, included algebra, series, functions, probability and statistics, and was more focused on practical applications of mathematics, especially those related to biology and economics.¹⁶¹ The 2MX course was, by contrast, more theoretical and included topics such as limits, derivatives, trigonometry and algebra. In grade 13, 3MX and 3MZ were offered as continuation courses in advanced level II. The more theoretical course, 3MX course included functions, integration, vectors and statistics while the more practical 3MZ course considered functions and a section on

linear programming. MX courses were designed for students interested in science and were more theoretical than the MY courses, gradually replaced by MZ courses, which were more applied. The 2MZ and 3MZ courses were being phased in as 2MY and 3MY were being phased out in the early years of this century.

5.6.5 Graduation Rates in Upper Secondary Mathematics

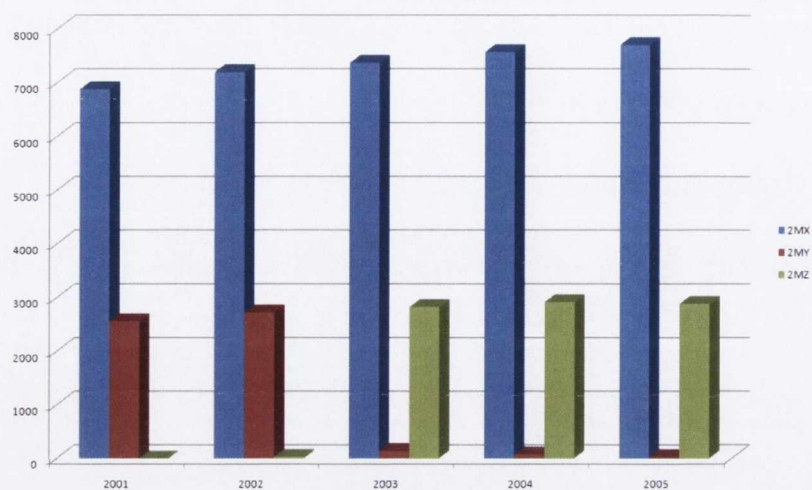
National data showing the uptake pattern of mathematics in the upper secondary cycle, foundation level, advanced level I and advanced level II, from 2001 to 2005 for students who were certified and achieved competence in mathematics (passed with grade 2 or higher) is depicted in Figure 5.8, Figure 5.9 and Figure 5.10 respectively.¹⁶²⁻¹⁶⁴ The tables from which these graphs are drawn are found in Appendix X.

Figure 5.8 Number of students who achieved competence in mathematics and were certified in the foundation course, at levels 1MX and 1MY, from 2001-2005.



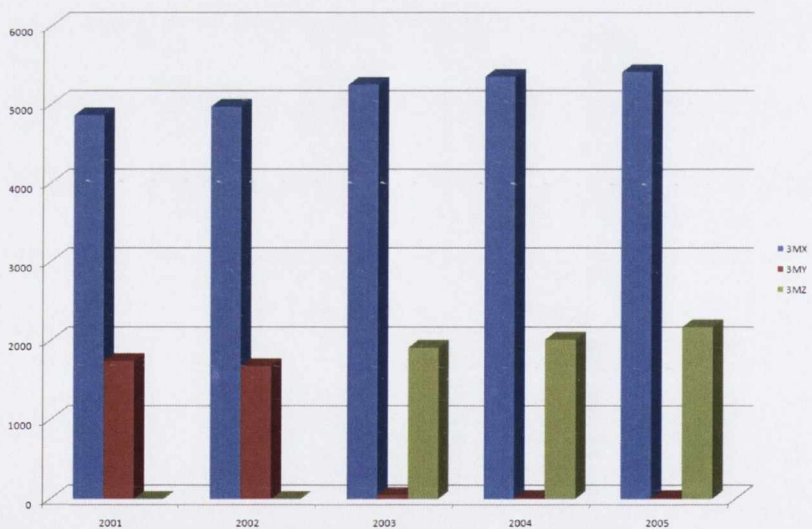
Source: Compiled by Author from data in Torbjørn Hægeland, Lars J. Kirkebøen and Jens Fredrik Baumgarten Skogstrøm (Upper secondary school competence in science and technology and applications to higher education) Statistics Norway, 41, 2007.

Figure 5.9 Number of students who achieved competence in mathematics and were certified in advanced level I, 2MX, 2MY and 2MZ, from 2001-2005.



Source: Compiled by Author from data in Torbjørn Hægeland, Lars J. Kirkebøen and Jens Fredrik Baumgarten Skogstrøm (Upper secondary school competence in science and technology and applications to higher education) Statistics Norway, 41, 2007.

Figure 5.10 Number of students who achieved competence in mathematics and were certified in advanced level II, 3MX, 3MY and 3MZ, from 2001-2005.



Source: Compiled by Author from data in Torbjørn Hægeland, Lars J. Kirkebøen and Jens Fredrik Baumgarten Skogstrøm (Upper secondary school competence in science and technology and applications to higher education) Statistics Norway, 41, 2007.

5.6.6 Mathematics Policy MST 2005

The *Research Council of Norway* (2002) undertook a review of mathematics in Norwegian Universities and Colleges.¹⁶⁵ Norway was promoting mathematics with the public at large,

through the Abel prize, through biographies about the lives of its' internationally renowned mathematicians, Nils Henrik Abel and Sophus Lie and through universities and college faculties visiting high schools (upper secondary schools). *Nomad*, the journal for research and development in mathematics education, in the Nordic countries, recognised five areas that needed political and academic attention: the recruitment of teachers, the content of initial teacher education, the relation between initial teacher education and school practice, the demands of a changing society and the need for further research on teacher education.¹⁶⁶

The *mathematics, science, technology* policy, MST 2005, indicated the way the Ministry and associated state organisations planned to cohere measures that they hoped would lead to improvement in uptake in mathematics.^{167,168} Measures included making mathematics compulsory in grade 12 of upper secondary education (the second year of the three year cycle) while the number of hours of instruction, in upper secondary mathematics, was increased by three hours per week.¹⁶⁹ Another measure included the establishment of a *National Centre for Mathematics Education*, in Trondheim on 1st August 2002, mandated to coordinate the development of new learning strategies in mathematics from kindergarten through to the level of teacher education.¹⁷⁰ Reform measures emanating from these developments included making mathematics compulsory in teacher education and the introduction of a new five year grant-aided masters' degree in mathematics.

5.7 Teacher Reform and Opportunities for Continuing Professional Learning

Based on a range of research findings the Ministry, in the early years of this century, concluded that teacher competence was the most significant factor in influencing student achievement.¹⁷¹ It was recognized that while teachers' subject expertise was important that pedagogical knowledge about learning was equally important.¹⁷² This changing conception of teaching was underscored by the need for a pro-active school management

(administration) and the elevation of the discourse on teaching and learning as *the primary purpose of the school*.¹⁷³ The Norwegian Board of Education (2003) expressed concern that the continuing professional development of the teaching force was mostly based on short courses, that appeared to be of little worth.¹⁷⁴ Teachers in upper secondary schools were qualified as either academic or vocational teachers and came from a range of initial teacher education programmes which are outside the scope of this study.

Inservice education was provided by the school, through school-based development planning and by the county education authority, in consultation with schools and the offices of the Ministry, through either short courses or longer accredited courses. There was an increasing range of university courses for inservice teachers and many teachers engaged in action research or action learning projects that often led to Masters' accreditation. Generally upper secondary academic teachers had qualified, prior to 1995, with subject specific degrees of five to six years duration, and a brief six month pedagogy course. After that time the pedagogy course was increased to one year in duration. Hansen and Simonsen (2001) noted the difficulty for teachers to be adept at differentiated teaching, using ICT as a pedagogical tool, given that at most they only received a short course in pedagogy in their initial teacher education:

Does it provide teachers with the ability to plan, execute and assess their own work through a process of reflection? During recent decades many new ways of organizing the training of teachers and student teachers have been put into practice. However, the fact that a mere 30 ECT credits are devoted to pedagogy – the subject that first and foremost trains teacher students in the fundamental principles of teaching and that provides a far deeper view of teaching than the mere transmission of basic facts – is a cause of major concern. It is difficult to see how training like this will provide real professional development.¹⁷⁵

Ottesen (2007) considered the process of reflection in the changing discourse on teacher professional development and suggested three models of reflection: for enculturation, for concept development and for imagined new practices.¹⁷⁶ Her research concluded that reflection for enculturation was the most common type found in the school. The guidelines

for teacher education in Norway stated that teachers needed competences for changing educational practices.¹⁷⁷

5.7.1 Upper Secondary School Teachers - Number, Type and Age

The number of upper secondary teachers in Norway increased exponentially in the period 1970-2003 as indicated in Table 5.11.^{178,179} The high number of teachers accounted for the main investment in education made by Norway.¹⁸⁰ By 2005 the total number of upper secondary teachers was 23,136 of which there were 12,209 men and 10,927 women.¹⁸¹ Teacher unions had an important say in the running of the school and the school principal had regular meetings with the union representative of the largest union in the school to agree matters. There were about ten education unions with a total of 150,000 members, 140,000 of these belonging to the largest union, the Union of Education Norway (*utdanningsforbundet*).^{182,183} This union, founded on 1 January 2002, had members throughout the entire education system.¹⁸⁴

Change in teachers' daily working conditions were negotiated nationally as part of a pay deal along with Reform-1994. Salary increases for teachers of 7.7%, from 1995-2005, were negotiated in return for longer teaching hours, higher levels of school-based responsibility and local involvement in flexible working conditions.¹⁸⁵ Full time teachers in upper secondary school had an average income of 291,600 NOK per annum; those with a higher university degree had an average income of 306,000 NOK.¹⁸⁶ A head of an upper secondary school had, on average an annual income of 364,8000 NOK.¹⁸⁷ The Norwegian teacher salary scale was low, compared to the OECD average, with little recognition given for experience.¹⁸⁸ Norway was also concerned at the ageing teaching force where the average age of teachers in upper secondary education had risen by 2003 to 48.7 years.¹⁸⁹

5.7.2 Inservice Education and Opportunities for Continuing Professional Learning

In 1998 the national framework for initial teacher education described the state's image of a desirable teacher as *a learned professional, a co-worker, a role model and a carer*.¹⁹⁰

The role of the state, in the provision of inservice education, changed, in the period 1995 to 2005, from governance and administration to guidance and quality control.¹⁹¹ In Norwegian terminology, there was a distinction between further studies which lead to formal acknowledgement in salary, *vidareutdanning*, and shorter courses in general inservice education, *etterutdanning*.¹⁹²

Table 5.11 Number of full-time teachers in upper secondary schools, 1974-2003.

Year	Total	Male	Female
1974-75	10 473	7 825	2648
1976-77	11 027	8 317	2710
1978-79	13 517	10 187	3330
1982-83	15 497	12 086	3411
1984-85	17 087	13 079	4008
1986-87	18 135	13 423	4712
1988-89	18 343	13 248	5095
1990-91	20,647	14,584	6,063
1992-93	20,729	14,371	6,358
1994-95	21,197	14,421	6,776
1996-97	21,105	13,892	7,213
1998-99	21,068	13,430	7,638
2000-01	20,567	12,776	7,791
2002-03	19,337	11,896	7,441

Up to the mid-1970's, participation in inservice education and development was generally on an individual and voluntary basis. Reform-74 gave a significant boost to in-service education with the introduction of what became known as Week 38.¹⁹³ This week, reduced the former 38 weeks of teaching to 37 weeks, and gave teachers the right and obligation to one week's inservice education and development annually. Solstad (1994) described the type of county based inservice programme as a *cafeteria principle* giving individual choice from the richest possible menu.¹⁹⁴

Teachers associations were not a strong feature of Norway's education system and it was only in the nineteen nineties that a movement had grown to unify subject teachers. For example, The Physics Teachers' Association was only founded in 1996.¹⁹⁵ The continuing professional development of teachers became a shared responsibility between state authorities at county level and school owners. The state authorities at county level included the local government authority, the county education office, and the voice of the *Ministry of Education and Research* at local level - the national education office. Concern was expressed at the relative lack of participation, by science and mathematics teachers, in inservice education:

When it comes to specific education in mathematics and science, the teachers are far below the international average. The level of MST education is also low. Teachers in mathematics and science participate to a strikingly small degree of inservice and continuing education relevant for the teaching of the subject.¹⁹⁶

School-based teacher education, quality in teacher education and competence development among the workforce, all became national priorities in the early years of this century. By 2005, the *Ministry of Education and Research* pledged NOK 375 million to school owners for the continuing professional development of teachers.¹⁹⁷ A general shortage of teachers possessing the required qualifications in science and mathematics become an area of concern with fifty per cent of teachers' with masters degrees over fifty years of age.¹⁹⁸⁻¹⁹⁹ This shortage was particularly acute in the physical sciences.²⁰⁰ Of these a total of 31.6% had lower university degrees with 18.3% having a higher university degree.²⁰¹ A survey by the *Norwegian Institute for Innovation, Research and Education* in 2002 showed that the number of science teachers with a higher degree decreased from 32% in 1972 to 8% in 2000.²⁰² In the first year of upper secondary education research showed that 8% of mathematics teachers had a Master's level degree in the subject.²⁰³ In the same study 7% of physics teachers, 11% of chemistry teachers and 31% of biology teachers had Master's degrees in their respective subjects.²⁰⁴

An improvement in performance and knowledge in MST will require both a higher level of knowledge in the subjects among the teachers and access to better teaching materials, factors which motivate, effective teaching strategies, efforts and mastery.²⁰⁵

Teaching contracts specified that teachers must teach for 190 days per year and this was divided into 38 weeks. A working year was designated as 1687.5 hours, and it comprised bound and unbound hours. Bound hours were largely tied to class contact teaching hours while unbound hours were reserved for planning, evaluation and in-service education. Unbound hours were at the disposal of the school principal for different tasks and duties.²⁰⁶ The working time arrangements for teachers before and after January 1994 are indicated in Table 5.12 and 5.13 respectively.^{207,208} Moller (1998) explained how each teacher was required to give 190 scheduled hours per year for school related duties:

The work-time agreement, which became effective from the 1st January 1994, requires the teachers to work 190 scheduled school hours per year, exclusive of their normal teaching hours. The 190 hours are divided, so that each teacher has 5 extra hours per week. In addition to these hours, each must participate in 5 days worth of joint planning/evaluation and training per year.²⁰⁹

Pilot studies with the *working hour agreement* in twenty six upper secondary schools in 2000-2001 indicated positive outcomes at local level based on team approaches:

Several of the experimental schools have made teacher teams the supporting unit in the organisation of the teaching. A well functioning team, aid and support for administration and time planning, sufficient teacher resources and suitable rooms for teaching and collaboration have proven to be important in order to be able to handle the challenges of a new organisation of work, and reap the rewards of the work for students and teachers.²¹⁰

The school package agreement in 2002 (*Skolepakke 1 and 2*) introduced reforms to the working conditions of teachers with greater flexibility in local negotiation.²¹¹ Coordination between subject teachers was regarded as good with assessment, tests and examinations, being the most common area for cooperation in the upper secondary school.²¹² The extent of teamwork in schools was noted by a European Commission expert group on a study visit in May 2003:

whereas the relationship earlier was characterized by individual organization, with limited co-operation and low degree of visibility toward each other, the reality today is greater visibility, extensive co-operation and more collective responsibility. However, the evaluation team observed considerable variation between the teams, both within the same school and between schools.²¹³

Table 5.12 Teachers' workloads in upper secondary education before and after January 1994.

Teaching Periods per week (before 1994)	Teaching Periods per week (after 1994)	Teaching Periods per year	Organized tasks Hours/year	Sub-total hours per year	Time for preparation hours per year	Total
17-22	15.7-20.7	598-785	190 + 37.5	825.5-1012.5	705-892	1717.5

Table 5.13 Organisation of upper secondary teachers' working time 2000-2003.

Year	Weeks of Instruction	Days of Instruction	Net Teaching Time (hours)	Working Time required at school (hours)	Statutory working time (hours)
2000	38	190	524	----	1718
2001	38	190	505	695	1718
2002	38	190	505	695	1718
2003	37	187	505	711	1680

The need for curriculum reform to be supported by teacher development, sensitive to the everyday classroom issues confronting teachers, was argued for by Broadhead (2001).²¹⁴

This need was reflected in the tension in dealing with a detailed prescribed syllabus on the one hand and the need to take learner's needs into consideration.²¹⁵ Broadhead (2001) argued that this conflict would only be resolved satisfactorily when policymakers, teachers and pupils were to regard themselves as joint and equal participants in a universal enterprise.²¹⁶ Broadhead (2002) argued for policy discourse to extend inside the schools and considered teachers as *next phase policy makers*.²¹⁷

5.8 Future Concerns in Norwegian Upper Secondary Education

Future concerns for Norwegian education were all primarily focused toward developing learning, the learning school, the teacher as professional learner and the learning society. This challenging aspiration was matched with substantial levels of investment and a multitude of reforms measures, including written policy documents on science and mathematics education and teacher education. The pedagogical approach of using *adapted teaching* (differentiated teaching) had become a statutory obligation based on section 1-2 of the Education Act 1998. Many research and development projects were being initiated and questions of pedagogical reform and pedagogical leadership in schools had taken on a new importance. The changing conception of teaching and the role of the teacher had changed, changed utterly, from times past. Norway had set an ambitious target and one that would not be easily achieved in a country where uptake in the physical sciences and mathematics, at higher levels of specialisation, was modest. This was further compounded by the average age of academic teachers at 48.7 years whose initial qualifications gave only meagre attention to pedagogy.

The Ministry established a *school development programme* at a cost of Euro 12 million (NOK 100 million).²¹⁸ The project was due to start in 2005 and run for four years. The introduction of a *Knowledge Promotion Reform* (2006) was aimed to progress learning and ensure that all pupils received a differentiated education.²¹⁹ The school was to be regarded more as the site of educational change with teachers playing a more significant role as *curriculum makers* with subject content and teaching methods to be decided for individual learners rather than centrally prescribed.²²⁰ The project planned to spend 600 million NOK in developing the competence of teachers and head teachers and to strengthen research in education.²²¹

Norway had aspirations to develop a groundbreaking school of the future with regard to the digital competence of the teaching force and their ability to use ICT to stimulate teaching for learning.²²² Sjøberg (2005) predicted a promising future for school science given that students, while not pre-packed with scientific knowledge, were gaining ground in something equally important, *the ability to learn*.²²³ The *Mathematics, Science Technology* policy was subjected to rolling review and an updated version for 2006-2009 was published.²²⁴ Goal B identified the need to improve teachers' qualifications and teacher training, including B5 which related specifically to improving teachers' qualifications in MST through *targeted continuing education and training of teachers*.²²⁵ In total the Ministry planned to invest NOK 2-3 billion approximately, from 2005 onwards, in developing the competence of teachers, school leaders and administrators to progress the development of a learning culture at the level of the school.²²⁶

5.9 Chapter Five: Summary

The essence of the evidence from this chapter is dealt with under the heading of the five key questions driving the macro-study.

Q1. What are the key features of the national policy process?

Norway has a system of public schooling that is decentralised, since the later 1980s, and includes the MER, the County Education Directorate in the nineteen counties and the schools. The system is consultative, dialogical and has a strong political undertone. Nylehn and Presthus (2001) describe the main roles of the school principal as managerial, pedagogical and political.²²⁷ In 2002, in response to the declining interest in the sciences and mathematics, Minister Kristin Clemet initiated the formulation of an MST Policy, a new policy for the promotion of mathematics, science and technology.²²⁸ The policy had a strong focus on strengthening the academic capital of teachers and the establishment of a

national policy forum, a protected space for all stakeholders to meet, including teachers, to discuss issues.

Q2. What is the changing shape of school organizational supports and structures in the 1960-2005 time-frame?

Structural reform was a strong feature of curricular reform in Norway. In the reform of 1994 a new middle management tier was introduced, involving new posts and structures. The new Heads of Department, including one for science and mathematics, had a reduction in teaching time with 70% administration and leadership duties and 30% teaching. They had a statutory obligation to convene meetings of the respective teachers and teachers were obliged to attend these meetings. This structured approach was in line with Rosenholtz's (1991) research on the development of the teacher as learner within a learning organization.²²⁹

Q3. Outline the key curricular and pedagogical reform waves in science and mathematics education in the 1960-2005 time-frame?

The main curricular reforms in the time-frame of this study were R-74 and R-94. R-94 focused on pedagogical reform. *Adapted teaching*, taking the subject and the age and developmental level of the student into account, became a statutory mandate Section 1-2 Education Act 1998. From the mid-1980s teachers became involved in the assessment of their own students. Marks for examinations ranged from 0 to 6 and the state only conducted a percentage of examinations (10 to 20% approximately) to retain national standards. These curricular waves in the sciences emphasised experimental work and the student taking responsibility for their own learning. Angell et al (2005) argued that physics teachers and their students were a closed system, traditional and theoretical in outlook.²³⁰ Valdermo (1995) suggested that chemistry needed to have a better connection to society.²³¹

Pettersen (2005) indicated that the biology syllabus was more content-led than inquiry-driven.²³² Mathematics was presented in 2000 with a constructivist and eclectic approach recommended, but with the caveat that there were important basic skills required for being proficient in the subject. These involve some routine mastery in much the same way that a musician needs be proficient in the playing of chords.

Q4. What is the changing role of the teacher and what opportunities are provided for continuing professional learning in the 1960-2005 time-frame?

The teacher was espoused in the policy documents, from 1998 onwards, as a learned professional, a co-worker, a role model and a carer. Teaching and learning was also elevated to the position of the primary discourse of the school. The reform in 1974 had introduced Week 38, one full week of inservice education. Solstad (1994) described the selection of many courses from a rich menu as giving a model of inservice based on a cafeteria principle.²³³ Monsen (2003) argued that older academic subjects, like science and mathematics, required models of inservice that engaged with the essentialist knowledge conception of teachers.²³⁴ Teacher qualifications had fallen from 32% with higher degrees (masters) in 1972 to only approximately 8% in 2000. The MST 2005 policy strategy aimed to improve the academic capital of science and mathematics teachers while Euro 12 million was invested in school-based development planning. Future policies offered opportunities for professional learning, supported by investment of 2-3 billion NOK.

Q5. What are the graduation rates in science and mathematics and the changing number of schools and teachers in the system?

Graduation rates were charted for the sciences and mathematics in the period 2001-2005. In 1960 the number of students graduating in the *examen artium* in the real science line was 2619. By 2005 the number of students graduating from the various science courses of

study shows an even distribution between all three science subjects with physics having a slight advantage, Table 5.14. Data for the uptake of mathematics in 2005 in the two levels of specialisation shows a big fall off from first year to second year in both the more theoretical courses (X-course) and the more applied Y-courses (later known as the Z-course), Table 5.15. By the third year of specialisation the number of students graduating was less than half of the number of students starting. By 2005 there were 454 upper secondary schools in Norway and a teaching force of 23,136 teachers.

Table 5.14. Graduate rates for physics, chemistry and biology in 2005.

Advanced Level	Physics 2FY, 3FY	Chemistry 2KJ, 3KJ	Biology 2BI, 3BI
Level I	5590	4669	4444
Level II	3011	3227	3226

Table 5.15 Graduation rates for mathematics, X and Y courses, in 2005.

Mathematics	X-course 1MX, 2MX, 3MX	Y-Course (later called Z) 1MY, 2MZ, 3MZ
Foundation Level	12,197	7,920
Advanced I	7,704	2,883
Advanced II	5,414	2,171

Chapter Six: *Policy as Professional Praxis* in Senior Cycle Science and Mathematics in Case Study Schools in the Republic of Ireland 2003-2004

6.1 Introduction

Chapter six considers the findings from the case study school research in Ireland in 2003-2004. This research study focused on science and mathematics reforms in the *Leaving Certificate (established)* programme. The science reforms promoted enquiry-based learning, ICT enhanced learning, self-directed learning and suggested a 70: 30 divide between pure and applied science. Mathematics reforms involved three different levels of specialisation, from highly theoretical to highly practical. The aim of this exploratory study was to gain insight into the complex social phenomenon, that was the policy implementation process, through tracking the organisational reforms being made at the level of the school and taking into account the perspectives of two key stakeholders, the voice of management and teachers, at one snap-shot in time. It was hoped that this real-life data would illuminate the policy process, assist in its reconceptualisation and identify areas for future research.

Teachers at the time were subject to a high degree of external control with curriculum content and modes of assessment externally regulated.¹ The principal and management regulated their access to resources and structured their time.² There were five case study schools in this research study. Data collection methods included questionnaires, semi-structured interviews and field-note observations. Inside each school two members of the management team were included, the principal and career guidance teacher, and four teachers – one physics, one chemistry, one biology and one mathematics teacher. In total there were twenty eight respondents giving the voice of ten management and twenty teachers. One teacher was a physics and mathematics teacher while another teacher was a physics and chemistry teacher.

The case report is written first as a single case study and then as a cross-case synthesis. Sensitive data, such as teacher qualification, was moved to the second phase of the multiple case study when findings were aggregated. This chapter considers each school under the headings: background and context, organisational supports and structures, the perspectives of management and the perspectives of teachers. Each school was categorised as *learning enriched*, *learning impoverished* or *moderately impoverished* based on findings that related to Rosenholtz's (1991) criteria for teacher professional learning: formal structures between management and teachers (for example, Heads of Department), collaborative practices, an evaluation culture and continuing opportunities for teachers to learn.³ In the first iteration the data collected was coded through the three sub-themes, pedagogy and assessment (PED), organisational reforms (ORG) and teaching as a professional praxis (PRAX). Quantitative data was organised into a series of tabular arrangements. In the second and third iterations the researcher deliberately sought rival explanations and questioned the self-reported statements of respondents. Finally it was decided, through consultation with my supervisor, that additional rigour and a more robust picture would emerge if the study identified the number of respondents adapting, remaining neutral or contesting the reforms (Table 6.1).

Table 6.1 The extent of adaptation or contestation of the reforms within the case study schools in 2003-2004 in Ireland.

+1	0	-1	- 2
Adapting the reforms	Neutral about the reforms	Contesting the reforms	Deeply sceptical about the reforms

6.2 Profile of the Case Study Schools

The five case study schools represented urban and rural schools, single-sex and co-educational schools in addition to each of the school types: vocational, voluntary

secondary and community/comprehensive schools. It included one fee-paying school and one Irish-medium *Gaelscoil*. The schools varied in size from an enrolment of 173 students to 700 students (Table 6.2). The teaching staff similarly varied from nine to fifty teachers, with each school having between three to nine science teachers and three to six mathematics teachers (Table 6.3). For purposes of confidentiality schools were given pseudonyms based on scientists and mathematics: *Boole, Hamilton, Hodgkin, Parsons and Walton*.

Table 6.2 Student enrolment in the case study schools.

School	Number	Male	Female
Boole	330	170	160
Hamilton	173	95	78
Hodgkin	700	0	700
Parsons	475	250	225
Walton	206	206	0

Table 6.3 Number of teachers in the case study schools.

School	Full-Time teachers	Male Teachers	Female teachers	Science Teachers	Male Teachers	Female Teachers	Maths Teachers	Male	Female
Boole	20	7	13	4	3	1	4	3	1
Hamilton	9	2	7	3	0	3	3	0	3
Hodgkin	50	5	45	9	1	8	6	0	6
Parsons	28	12	16	3	2	1	3	1	2
Walton	12	8	4	3	2	1	5	2	3

Case Study 1: Boole

(a) Background and Context.

Boole is a medium size rural vocational school, a community college with a mixed socio-economic intake. The pendulum swings more toward the disadvantaged than the advantaged side of the spectrum. The school is co-educational with a staff of twenty teachers. It had a total enrolment of 330 students in 2003-2004. Rural schools of this size often struggle to offer a full range of programmes and have minimal resources. This

school was no exception. The stated ethos is based on the development of high academic achievement coupled with whole person development.

(b) Organisational Supports and Structures.

Facilities in Boole are quite limited and while some parts of the school have been refurbished the entire building is in need of serious investment. The school has two science laboratories, one with internet access and datalogging equipment. There is one computer room. Standards are minimalist with no evidence of ongoing updates or demonstration models. The science budget is allocated on an *as needs arise* basis with the principal, under the guidance of the BOM, in control of resources. Analysis of the BOM minutes of meetings from 2001 to 2004 shows no mention of teaching or learning. There are no subject related Heads of Departments and no formal ways for science and mathematics teachers to meet within existing structures. However inservice education has been provided, through visits to the school by support service personnel, SLSS and SDPI, and inservice days in the region.

(c) Perspectives of School Management.

While the principal supported teachers attending inservice days he found this very disruptive:

I facilitate teachers as often as possible and if they want to go on in-service then I am all for that. Even though it is causing huge problems within the management of the school. I am not happy about how that is done but at the same time I am very supportive of teachers learning and gaining experience and ideas on the new, restructured syllabus. (*school principal*)

He was aware that science reforms involved mandatory experiments. He closely guarded the budget and teachers had to *come and ask for* whatever they needed. He noted that all science and mathematics subjects were offered at higher level and only later, if it became too difficult, did students proceed to lower levels. He questioned the value of foundation

level mathematics given it was not recognized for many further education courses. He explained the difficulty for teachers to change practices, and become evaluative, given their cultural inheritance:

I think it's still in the early embryonic stages in senior cycle. I think a lot depends on the culture we have grown up in ourselves and often teachers and people in the teaching system are products of the culture and they act out the culture they grew up in and it takes enlightenment of new ideas and new methods and exemplar methods of getting teachers to realise there is another way of delivering this message and getting (students) to understand and take on subjects. (*school principal*)

He favoured a number of assessment modes stating that the written examination in science is too restrictive. While the school had been involved in subject evaluations with the inspectorate, in subjects other than science or mathematics, he had not engaged in a formal system of evaluation at school level. The guidance counsellor advised students against specialising in science and suggested they take one or at most two science subjects in their final examinations.

(d) Perspectives of Teachers

Boole has four science teachers and four mathematics teachers at senior cycle. There were four teachers in this part of study, one each from physics, chemistry, biology and mathematics. None engaged in any type of formal written evidence gathering with respect to self or peer evaluation. All shared the belief that students should start at higher level and then failing this, should work their way back to ordinary level. While the science teachers favoured the introduction of an additional assessment component the mathematics teacher favoured the status quo. The physics teacher, with many years experience, regarded physics as a gate-keeper subject, not for the average student:

physics has been regarded as a difficult subject and that it is difficult to get the high points, you know to get the A1 or an A2 in physics. And students always have an eye to the points and if there is, on the option, if there is a subject that it's perceived it's much easier to get points then they opt for that. (*physics teacher*)

He perceived recent reforms to involve little more than reduction in mathematics content and an increased emphasis on practical work. He justified his traditional examination-focused approach on the basis that there was no credit awarded for other methods. He was not convinced of the value of using ICT as a pedagogical tool or the value of using data-logging when conducting experiments:

I am more a traditionalist..you have to be very very focused to use ICT. I would use it on occasions when there is something specific that I want to do but it would not be part of every lesson or it wouldn't happen every week even. (*physics teacher*)

However he was aware of the emphasis on connecting the subject to real world applications:

A student doing the new syllabus does not have to have the same level of mathematics as a student doing the old syllabus. That's one of the differences. There is some emphasis on science in society and so on that relates physics to the everyday world, and..there is something to be gained from that marks wise. So we can justify spending classes now and again explaining how physics is used in the real world and that is worthwhile. (*physics teacher*)

The chemistry teacher was teaching for only for a short few years. She had not studied chemistry in university so it was quite a struggle teaching the subject:

I hadn't studied it in college at all...I suppose being a teacher you know you kind of get confined sometimes to your own area and you are seen as teaching whatever and then my worst nightmare, in a way, came through. I was kind of told that somebody has to so I said 'Ok'. (*chemistry teacher*)

She had made considerable effort to become fully conversant with ICT and was attempting to vary her teaching methods and preplanning her methodologies, especially project work. It was for her willingness to innovate that this researcher placed her in the adapting the reforms category:

I'd be the kind of person that would have to get down to it andany time I would spend on that would be my own time, time out of school. But I suppose you like to keep on top of things...so I would be fairly comfortable around (data-logging). (*chemistry teacher*)

The biology teacher had many years of teaching experience. He viewed the new reforms as an opportunity to give young people a greater understanding of all life forms and to include more modern content, such as genetic engineering. ICT and data-logging were well outside his comfort zone:

to be very honest now, I would have avoided even finding out about it. And that's, I suppose, a failing on my part. But sure when the time comes we'll have to get up to speed otherwise we'll be dinosaurs. (*biology teacher*)

He did not always give students the opportunity to complete mandatory experiments:

with timetabling and without a lab technician and with a whole lot of factors, sometimes things get crushed and, maybe, when it should be a mandatory experiment, sometimes it appears like a very good teacher demonstration....I would teach sometimes like that. Because, if you have 24 in your class and everybody was to do it, it would be very time consuming and sometimes I find that that's not possible. (*biology teacher*)

However, this biology teacher taught for meaning-making, a central feature of the international literature on teaching for learning. This suggested to this researcher that he may not be that far away from a position where he would have ownership of the reform:

Some teachers might teach biology chapter by chapter. I wouldn't teach it like that at all. I would...connect things and by the time they would have completed their Leaving Cert year they would see that there is a massive web of living organisms and they are all connected. (*biology teacher*)

The mathematics teacher taught for several years. He had not attended a state-run inservice event in several years. The mathematics teachers held no timetabled planning meetings and saw little reason for a budget allocation:

traditionally, there are some subjects that are not on the budget list even and maths is one of them...whereas some subjects are very, very strongly represented on the budget list, for obvious reasons, you are not going to teach woodwork without wood, you need to buy timber..whereas we can actually get on with chalk so, get on! (*mathematics teacher*)

In his opinion he taught mathematics in a very traditional way:

I don't know if it is interest or ability, or energy or whatever it is, but I find myself sticking very much to the syllabus and, sort of, having almost a difficulty covering (the course) in the given time. (*mathematics teacher*)

(e) Boole School Profile – A Summary

The majority of science teachers and management in this case study school interpreted the science reforms to mean technical changes, such as student mandatory experiments, rather than deeper cultural changes that promote critical thinking, learning and pedagogical reform. The one exception is the chemistry teacher, who was using datalogging and a learner-centred approach to pre-planning teaching methods. The biology teacher, while proclaiming to be traditional may belong more in a twilight zone which many not be too far from the critical tipping point to adaptation of the reforms. The mathematics teacher was in a pre-reform world, he had not attended inservice in many years, saw no reason for a budget and had no time to teach using a variety of approaches to suit individual need. The physics teacher had a similarly traditional perspective. There was congruency in this case study between the perspectives of management and teachers, both clinging to traditional practices and a rather narrow interpretation of reforms. Management kept control of the budget, regarding it as a school budget, rather than a subject specific budget. They promoted academic success and considered that evaluation was new to the culture of schools. While science teachers had availed of recent inservice days these were regarded as *disruptive*. Based on Rosenholtz's (1991) criteria the case study report suggests that Boole is a *learning impoverished school* with respect to continuing opportunities for teachers to learn.

Case Study 2: Hamilton

(a) Background and Context

Hamilton is an all-Irish medium school, a Gaelscoil (*Coláiste lán-Ghaeilge*), under the auspices of the VEC, in an urban setting. It is both co-educational and multi-denominational. The Gaelscoil movement, gathering momentum since the early 1990s, has been largely driven by enthusiastic parents. This school is no exception and the parent

voice is strong. The intake is a mixed socio-economic cohort, skewed in favour of the advantaged, with parents typically having high cultural capital. The school is classified as a small sized school with an enrolment of 173 students in the 2003-2004 October returns. There are nine full-time teachers. The school's stated ethos is based on the promotion of the Irish language as a living spoken language, within the context of a holistic education and academic achievement. The school prides itself on the academic achievement of students with results for state examinations far exceeding national averages. The school offers all students the possibility of a three-year senior cycle. There is a system of bonus marks, a sliding scale, up to 10%, for answering state examination papers through Irish.

(b) Organisational Supports and Structures

The school offers physics, chemistry and biology in senior cycle depending on demand. This often means that physics and chemistry are offered on a rotating basis. Conditions within the school are cramped and facilities for science are generally inadequate and minimalist. There is a rather crowded staff room, one computer room and one science laboratory. The school has received the DES data-logging grant and is only now in the process of ordering this equipment. They do not have an ongoing budget for development of mathematics. Senior science teachers have all attended a number of national inservice days and have had school visits from each of the support service personnel. The senior mathematics teacher has not attended inservice days during her years teaching the subject, almost ten years.

(c) Perspectives of School Management

Both the school principal and guidance counsellor stressed the priority of academic achievement of their students. The guidance counsellor was acting in the role. The school has not been involved in an evaluation of any of the senior cycle science or mathematics programme in the previous three years, either internally or externally. The principal saw

evaluation more as inspection for monitoring rather than for illuminative and developmental purposes:

inspection is good if your house is in order, and the feedback is good and if it was made available of course to the staff and the board (of management) and people were very happy to see that the result of that was good. (*school principal*)

His knowledge of recent science reforms was limited to the introduction of mandatory experiments and he suggested that these should be assessed:

I don't know a huge amount about it in detail but I believe (there is) mandatory experiments as I understand it, and (they're) only going to be spot checked....So, I feel that they should have less experiments that are mandatory and be forced to go in there and do one of them in front of somebody or at least have a day when they're doing them that somebody may call, so that they know that they have to be able to do those experiments. (*school principal*)

The management and teachers in this school were very vocal about the need for all students to remain at higher level in these subjects until they could no longer cope. The Guidance Counselor suggested that students *broaden their horizons as much as they can* and did not favour of subject specialization:

Someone doing chemistry, physics and biology I would consider absolute lunacy...I would discourage that now...I would go on the record and say it. I would discourage anyone from doing three science subjects...In the current climate it is lunacy. (*guidance counselor*)

(d) Perspectives of Teachers

The voice of teachers in this school included the chemistry and physics teacher, the biology teacher and a mathematics teacher. In this study the senior physics and chemistry teacher has over six years experience. The senior biology teacher had a number of years of teaching experience. While the science teachers meet informally as a group they do not hold formal planning or evaluation meetings. The senior mathematics teacher has been teaching for a number of years. The mathematics teachers do not meet formally, as part of the structured time-table, for planning or evaluation meetings. The science teachers agree that assessment of mandatory experiments requires a second assessment component:

Current assessment is the Leaving Certificate (examination) paper – which is old fashioned at best. What about the use of colour – or photographs to accompany questions? English, Geography – all do this....what about project work with a mark (already decided) before the (final written) exam – what about a case study question (like geography) which involves a student (going on a) field trip? (*chemistry teacher*)

The physics teacher agrees that the 70:30 divide in the new syllabus gives a greater applied dimension. She is less sure that it promotes self-directed learning. She does not use ICT supported learning. The school has an academic focus:

We're very academic and we push really, really hard for academic results and with a hand on heart, I go exam paper and I don't go so much for the practical work and I know it's all changed towards practical work and we're supposed to go for it, but I focus pretty much on the exam papers and that said, if you look at the Leaving Cert mandatory experiments, they're not bad high tech. There are 30 mandatory experiments, I have set up to do 22 or 23 of them. (*physics & chemistry teacher*)

While the examination was still set using a pen on paper test she would not take the experiments as serious as the policymakers might wish her to and thought that this could only be changed when the assessment changed:

It would force teachers, it would force people like me who are cramming the exam papers, it would force us towards the practical (work) definitely. (*physics & chemistry teacher*)

In seeking to explain her teaching and learning approach she explained that while she did not use the text-book she did use a lot of reinforcement.

I'm a great believer in reinforcing....I like to bring them through it once and then come back to it again and come back to it again. I keep the pace up very much I've being lucky in terms of, we're very academic and most of the students that choose Chemistry and Physics for Leaving Cert are very, very bright anyway. (*physics & chemistry teacher*)

In her opinion the new emphasis on the lives of scientists was not really interesting to the students:

They said we were replacing it with information that the students would find desperately interesting and.....it's the most boring stuff ever....I think there are 35 people that need to be referred (to) while (the students) hate (this section). (*physics & chemistry teacher*)

The senior biology teacher regularly consults the syllabus, textbook and examination papers while only occasionally consulting the NCCA Guidelines and the Chief Examiners Reports. She uses some web-sites to illustrate aspects of the new biology course. The mathematics teacher has never attended a mathematics inservice event for senior cycle. She is satisfied with the current arrangement for assessment of senior mathematics. She was dismissive of the notion of using mathematical resources:

If you do have resources you are lugging them around to start off with which isn't practical. I haven't thought of this question for a while, I am so used to living without them. (*mathematics teacher*)

Case Study 2: Hamilton – A Summary

Hamilton has a conscientious management and teachers, well supported by parents and high academic expectations for their students. The focus was on higher level to the exclusion of other levels of specialization in science and mathematics. The management perceived the science reforms as being about student experiments. Evaluation was considered more as monitoring than development. The biology teacher used some web-sites and pre-planned teaching using a number of approaches and could, given favourable circumstances, be considered near to adapting the reforms. The physics-chemistry teacher was highly sceptical of the reforms, did not use datalogging, taught by reinforcing and suggested that many of the STS exemplars, such as the lives of scientists were boring. This teacher was not motivated to complete all mandatory student experiments. Excuses given were lack of facilities and the indisputable fact that senior cycle science subjects were assessed solely by written examination. The mathematics teachers had not been to inservice days, saw no value in having a budget for resources as she would only be *lugging them around*. She did not favour any change in the assessment format, preferring the final written examination. Hamilton had no designated budget for science and

mathematics and limited facilities. The school could be viewed as a *learning impoverished school* for teachers according to Rosenholtz's (1991) criteria and the lack of formal structures for collaborative dialogue and evidence-based reflective praxis.

Case Study Three: Hodgkin

(a) Background and Context

Hodgkin is an all-girls voluntary secondary school, owned and managed by a religious order. It has a mixed socio-economic intake. The principal explained that the intake was a broad spectrum ranging from the really affluent to the disadvantaged. The school is classified as a large school with an enrolment of 700 students in the October school returns for 2003-2004. There are fifty full time teaching staff. The school's stated ethos is one that is Christian with a holistic approach while striving for academic excellence.

(b) Organisational Supports and Structures

The science teachers have a designated science department and monthly meetings. The meeting are held during free classes and at lunch-time and are not time-tabled. They have a designated Head of Department, a special duties post. They have on average an annual budget of approximately Euro 2,500 to purchase equipment, replenish chemicals and repair equipment. The school also has, through the BOM, secured a part-time laboratory technician. The school has a tradition of students taking higher level mathematics and at 25% it is well above the national average. There is no designated convenor for the mathematics department. The group meet for approximately twenty to thirty minutes, about two to three times a year. They have approximately Euro 500 per year to purchase equipment. The teachers have not been involved in an evaluation of the senior cycle science or mathematics programme. However, some staff have been involved in an evaluation of their transition year, with feedback received from both teachers and students.

A new wing added two new science laboratories and a state of the art staffroom in addition to a technology suite. This investment cost in the region of Euro 150,000. The staff room has a central space for relaxing, a fully fitted kitchen and an open office space for teachers, each with their own designated desk with bookshelves. There are five science laboratories in the school, three older and two newer. Science teachers have internet access and data-logging equipment in the laboratories. There is one computer room and a technology suite. The school availed of all national support services, during 2003-2004, for science as well as the SLSS and SDPI support services, through both school visits and inservice days.

(c) Perspectives of School Management

The school is run on a day-to-day basis by the principal and two deputy principals. The school principal shows some knowledge of the reforms and a responsiveness in assisting teachers' implement the reforms:

the whole practical element has become huge. I think this is very good, I think certainly with chemistry it seems to be much more user friendly...The main support (we give) would be in the sense of having someone assigned as a lab person....she sets up experiments and she does practical work and organises stocks and whatever. We have had a huge amount of in-service..it has been a bit disruptive..teachers have been out of class a huge amount...and to get teachers to substitute who are qualified is almost impossible. (*school principal*)

The necessity of a laboratory technician was stressed:

it is not sanctioned by the Department, we are paying it out of own funds... but we see it as hugely valuable and I know teachers do as well...she can do part of the preparation so people have been doing practicals here for a number of years...I think the fact that that's not even thought of in certain circles...is a shame. Because, with all the practicals coming on (stream), it is a necessity, it is not a luxury anymore. (*school principal*)

She favoured incorporating practical assessment into the final examination:

If the weight is so much on practical work now you cannot reflect that on a written paper, it doesn't make sense to be writing about your experiment on a written paper (there) should be some way of acknowledging your practicals. (*school principal*)

This principal was aware that school leadership were expected to navigate a *whole new mind-set change* and this, in her opinion, challenged existing structures:

things have to be ironed out with the Department and ourselves to see how we bring the staff along, because I think for too long the staff has been left behind. ... there hasn't been enough in-service maybe around this whole area of inspection and..looking at teaching as a different profession now needs to be addressed....I think the Department needs to look at whole new models for second level schools, we are working out of something really from the last century still. (*school principal*)

(d) Perspectives of Teachers

The teachers interviewed for this study included one physics, chemistry and biology teacher and one senior mathematics teacher. Two of the science teachers favoured a second assessment for experimental work while the physics and mathematics teachers favoured the status quo. He presented a traditional essentialist philosophy and emphasized the mathematical dimension of the subject more than any other aspect:

A lot of the time you spend doing the mathematical side of it, because you know they are kind of weak at (this) and you want to bring them along a bit, it can become like a maths class a lot of the time. (*physics teacher*)

The chemistry teacher was teaching for less than ten years. While there were regular meetings of the science teachers she felt isolated with regard to teaching and learning:

I am definitely on my own, with respect to the teaching of (the subject) and I don't think I can approach anybody within the school. (*chemistry teacher*)

The 70:30 divide between pure and applied chemistry is more like 90:10 in her opinion.

She remained to be convinced of the pedagogical value of data-logging:

I don't have confidence (in it) at all, we have all the equipment, and it's a case of the lab technician would set it up and would tell us, well tell me, what works best. But I don't have a huge amount of faith in it...they are not going to be examined in it ...it is a case of you press this button and this button and there is your solution. As opposed to actually doing it and (working out) how you got there. (*chemistry teacher*)

The biology teacher, also head of science, had over twenty years teaching experience. She talked about the reforms in terms of the focus on practical work and the introduction of

newer areas, such as medical areas, which students find interesting. She was lacking in confidence with datalogging equipment. However digital cameras, in the laboratory, offered novel support for the write-up of the practical work:

We use the digital cameras in the practicals and so that we print them all in these little thumbnails, so that everyone for the practical would have a thumbnail, and if they don't want to be in the picture, it is their hands doing whatever it is; (for example) putting the little leaf on the petri dish. (*biology teacher*)

She was adapting the reforms and had, as a result of inservice days, written an ecology booklet with her other biology colleagues:

(We received) great practical help, great back-up..we went out and did ecology last year and we are now compiling booklets for our own students, based on the (inservice days) and setting up the station in a similar way. (*biology teacher*)

The mathematics teacher is teaching the subject for over ten years. She summarised her traditional stance to pedagogy when she explained that she had no requirement for additional teaching resources:

All I need is a marker and a text-book and set me off.....that is all it is, text book and exam papers. That is the whole secret, exam papers, exam papers, exam papers. (*mathematics teacher*)

She focused on mechanical mastery and had little empathy for self directed learning:

God forbid they came without their homework done. Their life is not worth living, no, no, no because if I put the effort into it, they put the effort into it and they understand that..a lot of the students..know my system and nothing deviates from that. Punctuality is vital. Come on time, do their work, they listen they pay attention, we'll have the craic...they get rewarded you know, the odd weekend and odd night they mightn't get homework to do, but for their good. (*mathematics teacher*)

She had never attended inservice days for senior mathematics:

I didn't get any...I didn't get a choice the first time it occurred, I think the other maths teachers would have got the choice because they are more senior. (*mathematics teacher*)

(e) Case Study Hodgkin – A Summary

Hodgkin is an all girls voluntary secondary school with a majority of students from advantaged backgrounds. Overall the school appears to be driven by an examination

machine within an academic focus. The organisational and structural supports and facilities for teaching are mostly excellent. The science teachers have a Head of Department and a regular budget in excess of Euro 2,500 per annum. They have access to a part-time laboratory technician, paid for by the BOM, and have a total of five laboratories, all with internet connection and datalogging equipment. The mathematics budget is more modest at Euro 500 per annum. The mathematics teacher emphasised teaching mastery of routines – *exam papers, exam papers, exam papers* - while the physics teacher emphasised the mathematics component of the subject. None of the science teachers were convinced of the value of datalogging. The chemistry teacher perceived that the 70: 30 divide between pure and applied science was in reality closer to 90:10. However the biology teacher, who was also the head of science, was adapting the reforms: as a result of inservice days she was working with colleagues to progress the teaching of ecology through writing their own resource materials. She was also using digital cameras in the laboratory to assist each student with their own personalised photograph of their experimental work.

Dissonance was found in this school between the school principal and the majority of teachers in this case study. The principal understood the nature of the reforms and was aware of the need for a *mind-set change* among teachers. She was clear about her pedagogical leadership role and suggested that newer models of schooling and different models of systemic inservice support were needed as the current system was working from a model *from the last century*. The school was regarded, using Rosenholtz's (1991) criteria, as a *moderately learning organisation* for the teacher as a professional learner.

Case Study Four: Parsons

(a) Background and Context

Parsons is a rural, co-educational community school. The school is classified as a medium sized school with an enrolment of 475 students in the October school returns in 2003-2004. It has a genuinely mixed socio-economic intake of students. The mission statement highlighted the holistic development of the student and the professional development of the teacher. It is owned and managed by the state and governed by a BOM directly answerable to the DES.

(b) Organisational Supports and Structures

The school has three science laboratories, with no internet access. These have minimal standards and are in need of modernisation. There is no annual science budget with teachers being provided with funding as requested. The school has two computer rooms. The school has availed of all the national support services during 2003-2004, with links to all the science support services, for physics, chemistry and biology as well as SLSS and SDPI. There are three science teachers and they meet about once a year for planning purposes. The senior mathematics teacher attends meetings of the local IMTA.

(c) Perspectives of School Management

The Principal is assisted by a Deputy Principal and a number of middle management posts of responsibility. The school has not been involved in a whole school evaluation in the previous three years, nor have any of the science subjects at senior cycle being evaluated either internally or externally. The school principal was aware that reforms in science involved a new emphasis on practical work. He carefully managed the school budget and preferred teachers to come to him rather than dispensing an annual budget to any specific department:

If you need something, you come to the table and you look for that...I've never refused a member of staff anything they wanted in their classroom ...but I don't allocate them €5,000 and say you have to spend that this year, but if you need €10,000 this year to do your job, you'll get €10,000. Now you might only need €2,000 the year after, and that's fine. I don't expect you to spend €5,000 just to satisfy a budget. Do you know, because the budget we get is for the school, and the way I look at it is, what's in the best interests of the school is what we'd spend it on, and I expect teachers to come and inform me, but I find that teachers here certainly, have been responsible in their resources, that they don't squander them. (*school principal*)

The school received Euro 29,000 for the upgrade of the laboratories, from the DES audit, and this had yet to be spent. The mathematics department rarely make a request for teaching resources preferring instead to run *on a shoestring*. The principal stated that he had two very good senior cycle mathematics teachers. They were from a traditional mould and taught in terms of mastery of drill and practice:

our maths teachers, they're cut out of a particular block, like, I can interchange two maths teachers, and the students would hardly notice...they produce the results... (but)...it's chalk and chalk. It's, put the example up there on the board, and then follow through, do it on the board, do it again on the board and do it again on the board, and now you go home and you try and do that for six times or seven times tonight, and in terms of six or seven questions for homework. (*school principal*)

(d) The Perspectives of Teachers

All three science teachers interviewed agreed that science needs a second assessment component to test experimental work. The mathematics teacher is satisfied with the existing assessment of the subject. The physics teacher has over thirty years teaching experience. He is concerned with the poor mathematical ability of students. He explained that he liked to use a transmission model of teaching:

my main methods of teaching (is), I suppose, a bit of chalk and talk.. although it's a white board we use now, and the overhead projector, and my computer. (*physics teacher*)

He was not convinced that the reforms had made any progress in tackling the perception that physics was a difficult subject:

The new syllabus has done nothing for that, you know, or any kind of programs they have of encouragement or anything like that, they haven't still dealt with the student's perception, physics is hard, that's it. (*physics teacher*)

The final written examination, in his opinion, drove the teaching and learning and suggested that little would change until a way of assessing mandatory experiments was found. The chemistry teacher is teaching for less than five years. She is confident in getting students engage in experimental work and for this reason was regarded as adapting the reforms. She is not so confident with datalogging, and occasionally falls back into transmission models of teaching:

for senior cycle, I use an awful lot of the overhead projector, so, we do questions on the overhead projector, I just write the question and then I'd have the answer, and they do it and then I can just know that it's brilliant teaching compared to the blackboard. (*chemistry teacher*)

The biology teacher has over twenty years teaching experience. The reforms in biology involved, in his opinion, making the course content somewhat shorter and giving a better connection to modern lifestyle biology. He also self-reported using a transmission model of teaching. Instead of using the blackboard he was using ICT applications, such as powerpoint presentations, in teacher-centred ways. He was not that conversant with experimental work. He found himself caught between three tensions: the need for senior cycle students to matriculate to higher level, the current assessment system and the espoused intentions of the official documents. He was placed in the deeply sceptical category in this study:

one is going to (do) what gets these (students) out of the school, into third level, because that is what the demand is out there, and you can have all the theories you like, but....the natural human response of a teacher... conscientious about the students in their care, is to get them to where they want to be, and more particular, where their parents want them to be, and so...until such time as credit (is) given for, actual hands-on and it's assessed, we're not going to have the benefits of what the curriculum inspires (us) to do. (*biology teacher*)

The mathematics teacher was teaching for over twenty years. The higher level had become more student friendly since the reform in 1992. Mathematics was, in her opinion, merely *a memory game*. She saw little point in teaching for understanding and for this reason was placed in the deeply sceptical category:

When I'm with the big groups I think it's chalk and talk still, to be honest....As regards resources, I just use as we say, the chalk, the talk and the text book. We have a Maths head of department, and she would have some little shapes and little things that we can access, but really at the end of the day, the chalk and talk, and I think the students will have to practice that, there's no point (in) explaining, they have to get the skills for themselves. (*mathematics teacher*)

With regard to assessment this teacher was content with final written examination papers and saw no opportunity in the current school system for self-directed learning:

The higher group, they need the time, and the lower group are not able to work on their own. I find students are more dependent on teachers today, they're not able to move themselves at all, you just have to be there directing them all the time. (*mathematics teacher*)

Case Study 4: Parsons – A Summary

Parsons was a rural co-educational community school under the auspices of the DES. The prevailing culture appears to be one of driving an examination-centred success culture. The majority of teachers, in this study, self-reported using a transmission model of teaching. The biology teacher, placed in the deeply sceptical category with regard to the reforms, explained the tension between wanting to help the student achieve matriculation and the espoused rhetoric of the curricular documents. The mathematics teacher fully embraced an essentialist epistemology and suggested that she taught using an unforgiving drill and practice routine. She saw no need for resources, had no time for self-directed learning and wanted the final examination system to remain unchanged. She saw no point in teaching for understanding: *there's no point in explaining, they have to get the skills for themselves*. The physics teacher used a didactic teaching approach and suggested that teaching and learning was influenced by the final assessment system. The chemistry

teacher differed in that she reported using a variety of teaching methods and, while she was not confident with datalogging, she was very confident in helping students with their experimental work. For these reasons she was considered to be adapting the reforms.

There appeared to be management-teacher dissonance in terms of budgets and resources. The school principal held high control of the budget and wanted each teacher to ask him individually for their teaching and learning requirements. According to Rosenholtz's (1991) criteria the evidence from this case study is that it is a *learning impoverished school* in terms of the development of science and mathematics teachers as professional learners.

Case Study Five: Walton

Walton is an all-boys fee-paying voluntary secondary school run by a religious order. The school is classified as a small school with an enrolment of 206 students in the October school returns in 2003. The intake of the school is from the advantaged segment of society, mostly middle and upper class. The ethos of the school is on the development of the student as an individual and on his spiritual and character formation. The cultural capital of the parents is seen in the choice of programme and level of specialisation offered: only programmes leading directly to university are offered, science subjects are all offered at higher level only and foundation level mathematics is not considered.

Typically 90% of final year students progress to university:

Most of our students would be ambitious towards third level and getting into the university system. In fact most of them will get into it, whether it is in this country or (somewhere) else. (*school principal*)

(b) Organisational Supports and Structures

Walton has a science department, a head of department and a budget in excess of Euro 2,500 per year. It has a mathematics department, a head of department and a budget typically in the region of Euro 500 – 1,000 per year. Facilities are variable and the science

laboratories and staff areas are in need of modernisation. Heads of department are paid a stipend for the position in return for their work and attendance at a regular committee meeting with the principal in matters relating to school planning. The school has three science laboratories and one computer room. There are six mathematics teachers in the school and they meet typically once yearly in their own time. With regard to the teaching and learning of mathematics, the teachers have access to a budget for resources, mathematical models and measuring equipment, internet access and an up-to-date library of mathematics books. They have not been involved in an evaluation of the school's mathematics programme. Recently they have had inservice days and school visits from the national science support services.

(c) Perception of Management

The school is managed on a day-to-day basis by the Headmaster and Deputy Headmaster. The religious order guarded their autonomy but must now comply with recent legislation (Education Act 1998) and establish a BOM. Working in partnership with lay people and sharing the decision-making process will be a challenge to an order who have had a long tradition of decision-making among themselves. The school principal knew something about the reforms in science education, especially the uncertainty caused when it came to trying to predict the new examination paper:

The Biology teachers will tell you that there are three different text books and that it is very difficult to interpret what the text books are saying, some are emphasising certain aspects of the curriculum and some are emphasising other aspects of the curriculum...it is difficult for the teachers and the students, are very nervous, particularly about Biology at the moment. (*school principal*)

The focus in senior cycle was on academic success:

they are very points oriented – these students know how to get points...I think the new grading system came in in 1995, and you will see there is a steady increase in our average points since then, they are obviously working harder, but they are also working smarter, and they are playing the subjects a lot smarter. (*school principal*)

(d) The Perception of Teachers

The voice of the teacher in this study included the voice of four teachers, one each from senior cycle physics, chemistry, biology and mathematics. None envisaged a space in the time-table for self-directed learning. All favoured another assessment component, except the mathematics teacher who wanted the status quo. They were not using datalogging equipment as it was only now being ordered. The physics teacher has thirty years teaching experience. He believes that the reforms have made the course more student-friendly, that it is less theoretical and has mandatory student experiments. This teacher is familiar with setting up experiments and was fullsome in praise for the recent manual for physics teachers produced by the DES:

I always have the syllabus in front of me when I'm teaching, always, cross checking. The manual that came from the Department of Education, the teachers manual, excellent, absolutely first class, and I didn't notice it being produced, and when it arrived I nearly danced for joy with it. There is an awful lot in it, background stuff that is helpful, but it also helps to nail down, I've used it and photocopied it for notes and all over the place you know. (*physics teacher*)

He used a variety of teaching strategies (practical work, demonstrations and software) and a number of different ways of presenting information:

I would have a library, a main science library that I would use is actually here, some reference books, I don't use video at all. I have the data projector and I use that sometimes, there is some good software, I personally prefer to use the actual equipment if we have it for demonstrations, the overhead projector of course is great. (*physics teacher*)

There was little room, in the race for points, for self-directed learning:

The people who are doing physics will generally will want to be getting as many points as they can out of it so that even if when you do get the syllabus covered there is a demand there for revision in areas where they might be a little bit weak so there tends to be very little time for (self-directed learning). (*physics teacher*)

He suggested that a fairer system for assessment of physics might include a 75% written examination and 25% practical examination with an oral component:

I would love to see some diversification of (assessment) and the format in which I would like to see it would be on the basis of the mandatory experiments and in the context of the (students) being supervised actually carrying out the experiments, but also discussing with who ever is examining them, what they are trying to do. In the event of something not working or whatever they can carry out the oral dimension and that way, they're not goosed if the equipment breaks down, or the gas is turned off or whatever happens. And maybe possibly at the end of the practical there might be a five minute oral on aspects of the syllabus that wouldn't be related to the practical necessarily. (*physics teacher*)

Despite his self-reporting as traditional it was clear that this teacher was adapting the reforms, especially in his use of the new DES manual relating physics to real world applications. The chemistry teacher has less than five years teaching experience. While the *science technology society* component was given a 30% weighting in the syllabus, this chemistry teacher called on this part of the course about 20% during class-time and judged that it was included in about 10-15% of the examination papers. He was not convinced of the educational value of datalogging:

I'd have to say I'm not a big fan of (datalogging). I think loads of science is lost in it. and I think, to me, even at the in-services it is just a phase, they are trying to make science trendy and I don't know if that's the way to go. (*chemistry teacher*)

The biology teacher has less than five years teaching experience. Recent reforms in biology changed a lot of the older content to more modern content, including biochemistry, genetic engineering and genetic fingerprinting. In his opinion, students were points-driven, with little interest in topics outside the course. He favoured assessment of the practicals as he thought that might catalyse students into taking this aspect seriously:

Assessment is the tail that wags this particular dog, and if they don't wrap their heads around that I just don't think it's going to happen. (*biology teacher*)

The mathematics teacher, also the physics teacher, was teaching for thirty years. Mathematics teachers had only recently formed a department and had this year, approximately Euro 1,000 at their disposal for the purchase of computer software. They already had large sets of mathematical instruments. He found the syllabus very long and did not have time to consider alternative approaches:

I'm really tight on time, that is my biggest problem in maths, if I was to nail it down, I literally, I have a crowd in 6th year, they are a very good group, but I still have one full topic and part of a topic to cover, you know, and... I honestly feel that I can't afford to miss a day being sick, because it's that tight, to get the syllabus covered. (*mathematics teacher*)

(e) Case Study 5: Walton – A Summary

According to management students in Walton were almost all guaranteed some type of access to further study, the majority achieving university entrance. The curriculum and level of specialisation were carefully chosen to facilitate this academic opportunity. Structures were in place to ensure that science and mathematics teachers were engaged in planning: there was a Head of Science and a Head of Mathematics. These were paid a stipend for special duties with respect to these subject areas. They had access to specific budgets, approximately Euro 2,500 for science and Euro 1,000 for mathematics. Teachers had recently taken part in inservice days and had school-based visits from the science support services.

The physics teacher was using a range of teaching approaches and consulted the new DES manual to relate physics to everyday life. He was therefore considered to be adapting the reforms. While he felt pressed for time when covering the mathematics course he was engaged in the purchase of software for teaching the subject. The chemistry teacher was only a few years teaching but reported using teacher-centred ways. The biology teacher taught to the examination and suggested that he would only change this pedagogical approach when assessment changed. There appeared to be general agreement between teachers and management in Walton about the importance of academic achievement. While some supports and structures were excellent for the teaching of science and mathematics the laboratories needed refurbishment. Walton was classified as a *learning impoverished school*, according to Rosenholtz's (1991) criteria, as evidence from the study

indicated it was overlooking the development of its science and mathematics teachers as professional learners.

6.3 Cross-Case Synthesis

In general these five case study schools present a picture of management and science and mathematics teachers working conscientiously for academic progress of their students, working oftentimes at a frenetic pace trying to cover the course. The underlying cultural context in all schools is the moral obligation management and teachers feel toward getting students to achieve access to higher education. Four of the case study school managements, Boole, Hamilton, Parsons and Walton, directly mentioned this academic focus. This was strongly expressed by the biology teacher in Parsons who presented it as a dissonance between the espoused rhetoric of the policy documents and the day-to-day reality of the classroom. A similar argument was used by the physics-chemistry teacher in Hamilton.

The five mathematics teachers self-reported focusing on trying to cover the course in a limited time-frame. They used chalk-an-talk and questioning as their most frequently used teaching method (Table 6.4). Four out of five mathematics teachers saw no value in teaching resources. However the mathematics teacher in Walton was about to purchase software for teaching the subject.

Table 6.4 Teaching methods espoused by mathematics teachers.

Teaching Approach	Frequently	Occasionally	Rarely	Never
Pair-Work	0	5	0	0
Questioning	5	0	0	0
Logic Puzzles	0	3	1	0
Worksheets	2	1	2	0
Computers	0	0	1	4
Project Work	0	1	1	3
Chalk-an-talk	5	0	0	0
Field-Trip Outdoors	0	0	2	3

Science reforms were perceived, by the teachers, as being about increased student experimental work, more modern subject matter and a less mathematical approach for physics and chemistry. Management in Boole, Hamilton and Parsons perceived the science reforms as being about student experimental work. Management in Walton was concerned with the nervousness of biology teachers and students facing a new examination format. The principal in Hodgkin claimed the reforms signalled a mind-set change and that, as such, new structures and supports needed to be negotiated. In their questionnaire responses science teachers showed they understood most aspects of the reforms with slight ambivalence expressed with regard to the need for mandatory experiments (Table 6.5). Only one teacher in the five case study schools in this study, a chemistry teacher, claimed competency with datalogging.

Despite claiming to be traditional, this study found that four science teachers were adapting the reforms – a chemistry teacher in Boole and Parsons, a physics teacher in Walton and a biology teacher in Hodgkin. The study also located two other teachers near the reform tipping point – the biology teacher in Boole and the biology teacher in Hamilton. However the replication trend found in this multiple case study was the level of contestation of the reforms by the majority of management and teachers in this study (Table 6.6). This included twenty two respondents, from a total of thirty voices in the study. Four of these respondents were deeply sceptical of the learning reforms, a chemistry teacher in Hamilton, a biology teacher in Parsons and two mathematics teachers, one in Hodgkin and the other in Parsons. All four teachers expressed strong teacher-centred and examination-centred approaches to their teaching. All based their justification on the assessment system.

Table 6.5 Teachers’ perspectives on key aspects of the science reforms.

Reform	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
70% 30% Greater applied dimension	1	7	5	1	1
Promotes self-directed learning	0	8	2	3	2
Develops critical thinking	1	8	1	4	1
Taught in a practical and experimentally based way	4	4	5	2	0
Develops a better school-industry link	1	6	4	2	2

Table 6.6 The extent of adaptation or contestation of the reforms by management and teachers in the case study schools in Ireland.

School	+1	0	-1	-2
Boole	1	1	4	0
Hamilton	0	1	4	1
Hodgkin	1	1	3	1
Parsons	1	0	3	2
Walton	1	1	4	0

Numerical data was also a small yet significant feature of this part of the study. The investigation into the organisational supports and structures showed great variety between schools. Field-notes charted the conditions, varying from minimalist in two of the schools to state-of the-art in one school. This latter school also employed a part-time laboratory technician and a Head of Department for the science teachers, with an open and transparent budget for both science and mathematics (Table 6.7 and Table 6.8). Teacher meetings, for science and mathematics teachers, generally did not happen within formal time-tabled structures in any of the schools.

There were small class sizes in the physical sciences in 2003-2004, typically less than twelve students, with a very small number of students, from one student to six students, taking the ordinary level course (Table 6.9). Data for enrolment in Biology, while they

show a bigger number of students taking higher level, also show a poor enrolment for ordinary level (Table 6.10). While mathematics enrolment, in higher and ordinary level, is similar to national patterns this study shows poor enrolment in foundation level with only one school taking the option in this study (Table 6.11).

Table 6.7 Science structures in the case study schools.

School	No. of Labs	Internet Access in Labs	Computer Rooms	Science Budget	Science Teacher Meetings (approximately)
Boole	2	In one lab	1	As requested	Informally
Hamilton	1	No	1	As requested	Informally
Hodgkin	5	Yes	2	≥ €2,500 per annum	2 meetings per term
Parsons	3	No	1	As requested	1 meeting per year
Walton	3	No	1	≥ €2,500 per annum	Informally

Table 6.8 Mathematics structures in the case study schools.

School	Mathematics Budget	Mathematics Teacher Meetings (approximately)
Boole	As requested	Informally
Hamilton	As requested	Informally
Hodgkin	≥€ 500 per annum	2/3 meetings per year
Parsons	As requested	Informally
Walton	≥€ 500 - €1,000 per annum	Informally

Table 6.9 Student enrolment in physics and chemistry in the final year of Leaving Certificate (*established*).

School	Physics						Chemistr y					
	Higher	M	F	Ordinary	M	F	Higher	M	F	Ordinary	M	F
Boole	6	4	2	6	6	0	3	2	1	1	0	1
Hamilton	5	5	0	0	0	0	0	0	0	0	0	0
Hodgkin	20	0	2 0	0	0	0	34	0	3 4	0	0	0
Parsons	9	8	1	3	2	1	11	3	8	1	1	0
Walton	8	8	0	0	0	0	11	1 1	0	0	0	0

M = male

F =female

Table 6.10 Student enrolment in biology in the final year of Leaving Certificate (*established*).

School	Biology					
	Higher	M	F	Ordinary	M	F
Boole	12	5	22	0	0	0
Hamilton	16	5	11	0	0	0
Hodgkin	68	0	68	19	0	19
Parsons	17	4	13	7	2	5
Walton	23	23	0	0	0	0

M = male

F =female

Table 6.11 Student enrolment in mathematics in the final year of Leaving Certificate (*established*).

School	Mathematics								
	Higher	M	F	Ordinary	M	F	Foundation	M	F
Boole	13	7	6	16	8	8	6	5	1
Hamilton	11	5	6	11	5	6	0	0	0
Hodgkin	75	0	75	84	0	84	0	0	0
Parsons	15	7	8	54	34	20	0	0	0
Walton	14	14	0	14	14	0	0	0	0

M = male

F = female

Teachers were considered for their years of experience, qualifications and their membership of a voluntary subject association, either ISTA or IMTA (Table 6.12). Of the twenty subject teachers in this exploratory study only three teachers had qualifications higher than degree level. Seven teachers were teaching subjects that were not included in their final degree subjects. None of the mathematics teachers had mathematics as their major degree subject. 50% of the teachers were networked to their voluntary subject association, either the ISTA or IMTA. This indicated that the academic capital of science and mathematics teachers in the case study schools was rather modest and in need of continuing educational development.

In conclusion the multiple case study research in Ireland shows that the majority of management and teachers, in each case study school, shared a traditional mind-set with

regard to the teaching for learning paradigm. Organisational structures and supports were variable and ad-hoc and only two schools had heads of departments and ring-fenced budgets. All teachers in the study indicated that they had not taken part in a formal evaluation of their science or mathematics programme. Teachers in the study did not appear to follow Hargreaves and Goodson's (1996) model of the *post-modern professional*. Their model of the *flexible professional* seemed more appropriate, indicating a shared sense of community, with the possible weakness that there was little room for intellectual challenge in a practitioner-practitioner based informal dialogue. One rival explanation that held some logical coherence was the fact that upper secondary academic education was the gateway to higher and continuing education. Entry was by a state examination route that, for science and mathematics, focused on written examinations. It appears, from these case study schools, that this highly influenced perspectives on pedagogy and assessment. Another rival explanation that held logical coherence was that despite claiming to be traditional teachers, there may be additional evidence that might suggest that some of these teachers were engaging in more learning-centred approaches, to their pre-planning for the classroom experience.

This detailed study of the case record, using rival explanations, yielded four teachers adapting the reforms. Dissonance was found in the perspectives of the management and teachers with one school principal, in Hodgkin, showing an understanding of the reforms and questioning the model of inservice education and the approach taken to developing the teacher as a professional. Finally, while only one school in this study, Hodgkin, could be called *moderately learning enriched*, the main stumbling block for each school was their lack of formal structures for science and mathematics teachers to plan, meet and evaluate. These were also systemic policy issues in Ireland as may be seen from Chapter Four.

Table 6.12 Experience and qualifications of teachers in this research study.

Teacher	Years	Main Degree (Subjects)	Higher Qual(s)	ISTA /IMTA
Physics	30	BE (engineering)	No	No
Physics	8	BSc (chemistry)	No	No
Physics	35	BSc (physics/chemistry)	No	Yes
Physics	23	BSc(hons)physics/mathematics	No	No
Physics	8	BSc (physics, chemistry, mathematics)	No	No
Chemistry	3	BSc (hons. Chemistry)	No	Yes
Chemistry	2	BSc (physics/mathematics)	No	Yes
Chemistry	3	BSc (biochemistry)	No	No
Chemistry	8	BSc (chemistry)	No	No
Chemistry	3	BE (chemistry, biology)	No	Yes
Biology	28	BSc (rural science)	No	Yes
Biology	22	BE (PE/chemistry)	Diploma	Yes
Biology	25	BSc (physics, mathematics)	M.A.	Yes
Biology	1	BSc (botany)	No	No
Biology	8	BSc (biology)	PhD	Yes
Maths	30	BE (engineering)	No	No
Maths	8	BA (gaeilge, mathematics)	No	No
Maths	21	BA (economics, mathematics)	No	Yes
Maths	15	BA (economics, mathematics)	No	No
Maths	26	BE (PE/mathematics)	No	Yes

6.4 Chapter Six: Summary

The evidence from this exploratory case study research is now reflected on through revisiting the original research questions:

Q1. What can be learned from a study of the micro policy process in 2003-2004?

The busyness and exertion of the management and teachers is to the fore in this case study research with only one principal, in Hodgkins, acknowledging their pedagogical leadership role and questioning the model of continuing education for experienced teachers. The reforms were challenging the traditional mind-set of both management and teachers. The level of contestation of the reforms was consistently high, from school to school, leading to a chain of evidence being established in this study. This replication trend, twenty two respondents from a total of thirty voices, was challenging policymakers to reconsider the extent to which schools could fulfil their moral obligation to help

students achieve access to higher education on the one hand and take time, on the other hand, to facilitate self-directed learning.

Q2. How are the policy reforms being adapted inside the schools through changes in school organizational supports and structures in 2003-2004?

These five case study schools varied in their infrastructure and supports for their science and mathematics teachers. Hodgkin had five laboratories, three of whom were new state-of-the-art designs. It also had a part-time laboratory technician, a head of department, formal meetings of science teachers, and a designated annual budget. It had a more modest budget for mathematics. Walton had Heads of Department and a budget for science and mathematics. The other three case study schools had no formal structures for science or mathematics teachers to meet or designated budgets for ongoing resource development. Resources were supplied on an individual basis *as need arises* and teacher subject meetings remained informal, ad-hoc and variable.

Q3. How are the policy reforms being perceived inside the schools by management in 2003-2004?

Management, focusing on academic success, perceived that the policy reforms in science involved the introduction of student experiments. Only one school principal, in Hodgkin, mentioned the need for new structural supports for the reforms that were, in her opinion, seeking a mind-set change. None had been involved in an external subject evaluation of science or mathematics. The principal in Hamilton perceived evaluation as a bureaucratic and monitoring exercise while the principals in Boole and Parsons noted that it was challenging the existing culture and would take time to become established.

Q4. How are the policy reforms being perceived inside the schools by teachers in 2003-2004?

Science teachers, in these case study schools, had attended inservice days and had regional support teams visit them in their schools. Four of the fifteen science teachers were

adapting the reforms, using resources provided and making resources for their students – chemistry teachers in Boole and Parsons, a physics teacher in Walton and a biology teacher in Hodgkin. In addition two teachers (the biology teacher in Boole and the biology teacher in Hamilton) were at the tipping point between remaining with their inherited approaches and changing their mind-set. At the other end of the spectrum four teachers – a physics-chemistry teacher in Hamilton, a biology teacher in Parsons and two mathematics teachers in Hodgkin and Parsons - were deeply sceptical of the reforms. They all cited the written nature of the final state examination system as their justification for not engaging more fully with the reforms. Teaching as a professional praxis required, at a minimum, collaboration with colleagues and the development of a culture of evaluation. This study was concerned with the infrastructure for formal meetings between teachers and formal lines of communication between teachers and management. All teachers in the study indicated that they had not taken part in an evaluation of their science or mathematics programme. Three principals, Hamilton, Parsons and Boole, explained that evaluation was new and signalled a break with inherited practices. The principal Hodgkin called for a new approach in this regard.

Q5. What can be learned from a study of a range of quantitative findings including school profiles, teacher profiles and uptake in the sciences and mathematics in 2003-2004?

Uptake in the sciences and mathematics, relative to the sizes of the schools, compared favourably with national statistics. The uptake in ordinary level science was generally low and was not considered as a course of study in it's own right. Seven teachers, in this study, were teaching subjects that they were not qualified in while the number of teachers with higher degrees, three teachers out of twenty teachers, suggested a rather modest academic capital and a pressing need for further continuing education of the teaching force. Further large scale research was required to illuminate this issue.

Chapter Seven: *Policy as Professional Praxis* in Upper Secondary Science and Mathematics in Case Study Schools in the Kingdom of Norway 2003-2004.

7.1 Introduction

Chapter Seven presents the findings from five case study schools in Norway in 2003 – 2004. In total there were twenty seven respondents in the study giving thirty voices, twenty teachers and ten management. Three teachers taught two different subjects: one teacher was a chemistry and biology teacher and two teachers were physics and mathematics teachers. The ten voices of management included two school principals, two deputy principals, two guidance counsellors and four Heads of Department. Field-notes, questionnaires and semi-structured interviews, similar to those for Ireland, were adapted to suit the upper secondary curriculum in Norway. The questionnaires were piloted through two teacher educators in Norway and adjusted according to recommendations received. All respondents were fully conversant in English. Questionnaires were distributed in both Norwegian and English and all interviews were conducted in English. Research in Norway involved a number of study visits to the country. The preliminary study visit assisted in gleaning some initial understanding of the system before the case study research was conducted. Data collection and data analysis was validated through an extensive number of different cross-checks and tests dealt with in detail Chapter Three, section 3.6.

The chapter firstly considers some essential features of all upper secondary schools in Norway. It then profiles each case study school in turn under the headings: (a) background and context (b) organisational structures and supports (c) perspective of management (d) perspective of teachers and (e) a summary of findings. Data analysis was based on the theoretical framework for the study. The numerical data was sorted into a number of

different tables and the narrative was initially categorised into PED, ORG and PRAX representing the three sub-themes: pedagogy and assessment, organisational reforms and teaching as a professional praxis. The case study notes were then revisited several times, searching for rival interpretations and identifying the number of respondents who were either adapting or contesting the reforms. Based on advice from my supervisor this was quantified to improve the rigour and depth of the final case report.

Rosenholtz's (1991) criteria are applied to classify each school as *learning enriched*, *learning impoverished* or *moderately impoverished* based on the opportunities for developing the teacher as a professional learner. Some numerical data from the schools, regarding the uptake of the sciences and mathematics, the structures for science and mathematics and the qualifications of teachers, is presented. This is followed by a cross-case synthesis of the five schools and ends with a summary which presents an illumination of the evidence found under the five key questions driving the study.

7.2 Some Features of the School System in Norway

Upper secondary schools typically start the school day at 8am and finish at 3pm. Classes are time-tabled for periods lasting ninety minutes each, with a short break before each class starts. This applies to all subject areas including mathematics. In Norway recruitment, selection and appointment of upper secondary teachers is made by the school management.¹ By 2003-2004 practices between schools varied leading to schools marketing themselves and increasing the level of competition for places in various areas of study.² Schools were given greater autonomy:

the schools have been, set free economically which means that if we ran over budget one year we carry the negative balance with us into the next year also if we run a surplus we carry the surplus with us and that was never the case (before) (*head of department*).

Schools are co-educational and there is no history in Norway of single-sex schools. Upper secondary schools for post-16 education are generally in separate buildings from lower

secondary. Teachers are not obliged by law to offer constant surveillance. One principal noted that when teachers had their weekly staff meeting, one class period per week, that students worked independently and unsupervised:

Up to tenth grade (you are legally obliged to supervise at all times) yes, whereas for 11th, 12th, 13th grade, no....on Wednesdays, this fifth lesson, all teachers disappear into their (staff quarters) and there are no teachers among the students, and no problems...there are no problems...there has never been a problem. (*school principal*)

7.3 Profile of the Case Study Schools

The five upper secondary schools varied in terms of total student enrolment from 371 students to 777 students. The number of full-time teaching staff and the total student enrolment in grades eleven, twelve and thirteen in each of the case study schools are indicated in Table 7.1 and Table 7.2 respectively. Each public school in Norway in 2003-2004 is obliged to spend 10% of its budget supporting local art. This is in evidence in all five schools whose walls are generously adorned with art work. A number of pieces of sculpture are in evidence as well as extensive social seating. Each school has a canteen for students and staff. Each school has its own separate staff quarters and science and mathematics teachers, have their own designated work stations. The Head of Department, for science and mathematics, has a separate office in all cases. For purposes of confidentiality the case study schools are given pseudonyms based on the names of well-known mathematicians and scientists: *Abel, Bohr, Franklin, Watson* and *Curie*.

Table 7.1 The number and full-time teaching staff in the case study schools 2003-2004.

	Abel	Bohr	Franklin	Watson	Curie
Total	85	36	41	84	87
Male	36	24	28	35	43
Female	49	12	13	49	44

Table 7.2 Student enrolment in the case study schools 2003-2004.

Students	Abel	Bohr	Franklin	Watson	Curie
Total	777	371	560	603	507

7.3.1 Case 1: Abel

(a) Background and Context

Abel is a large urban school with 777 students and 85 teachers. It offers three lines of study, one academic line and two vocational lines: *general, economic, and administrative studies; sales and service and health and social studies*. The school prides itself on its academic results and the quality of its teachers:

Last year we were the school in the nation that came (very high) for results and we are proud of that...There are teachers at other schools might argue that, that's because we get ..students that are competitive at enrolment but we do manage to keep the level high and we are proud of that. That we don't teach a wishy washy science..we have dedicated teachers who are high quality. (*head of department*)

(b) Organisational Structures and Supports

Physical conditions in the school are very comfortable with separate staff quarters and an office block for management. The school has four science laboratories, for general science, physics, chemistry and biology. The laboratories are being redesigned, costing in the region of Euro 200,000, with a special emphasis on team work which is currently being promoted in the sciences. They have an ongoing annual budget of approximately 120,000 NOK (Euro 15,000) for science and mathematics, used to purchase books and resources, send teachers on inservice courses and update laboratories. Science teachers were singled out last year for a salary increase:

the state also decides sometimes to reward particular subject teachers over others and science teachers were one of those last year. So the science teachers got a raise that nobody else got. Not very popular in the school generally. (*head of department*)

(c) Perspective of Management

The Head of Department has over eleven years teaching experience. She convenes about ten time-tabled meetings of the science and mathematics teachers per year in addition to

their general staff meetings. This head of department, also the biology teacher in this study, tries to give attention to her pedagogical leadership role:

I see the pedagogical leadership as the most important thing that I do. That might mean supporting a teacher it might mean encouraging them to try a new way of teaching. It might mean redesigning a lab to work better so that then they can teach the way that they are supposed to. To me that's the most important thing. (*head of department*)

She notes that the state is promoting differentiation, to suit individual need, but observes that the current seating arrangement in classrooms don't support this:

Classrooms don't promote it. The classrooms are still desks and chairs looking straight at the chalk board. But the labs however have been redesigned and some of the computer rooms have also been redesigned where students sit around round tables or somewhere round tables where they are looking at each other instead of looking straight ahead...the chairs are moveable, most of them are on wheels, so that if the teacher wants to give an introduction for fifteen minutes maybe a new topic then the teacher can stand at the chalk board...and discuss the new topic and introduce it before they break up into groups. (*head of department*)

The school is involved in two experiments: one on learning and the other on teaching and learning mathematics. They divide the mathematics year group into a large lecture format followed by small group work:

We have 240 first year students and so we took sixty of them and put them in an auditorium with a teacher and that teacher then taught to sixty students for about forty five minutes each time that they met. Then after the forty five minutes the students were divided into three groups of twenty (students) and they each had a teacher then for (another) forty five minutes. The students were pleased with it. Some were pleased because they felt that the quality went up (at) this end. Some were pleased because they felt that they were able to get more contact with the teacher. (*head of department*)

This experiment had been evaluated by both teachers and students and overall the results are positive with a number of minor alterations planned for next year. They are also trialling another experiment on self-directed learning. The pressure for this appears to be coming from the university sector where many students are failing their first year. The experiment this year gave some independent study time to third years. It did not work, as

the students by then had already become too teacher dependent, and next year they plan to trial it with first year students. The teachers feel responsible for *covering the course*:

we have a department meeting now on Thursday and we will be bringing up this topic and the teachers are against it. They find it very difficult; they feel that their responsibility is to get through the material.....rather than what the students have learned; they don't see it that way..that their responsibility is to cover the material.
(*head of department*)

This older paradigm of teaching and learning was challenging a newer conception of teaching and learning. This head of department spoke of the future and the fact that most of her science and mathematics teachers were averaging 56 years to 58 years old with a number of teachers retiring at 62 years old:

I almost can't predict the future because I am loosing some very good, very traditional, very conservative but very good teachers. (*head of department*)

(d) Perspective of Teachers

The teachers in this case study all have over 10 years teaching experience. The physics teachers in the school have a reputation for investigations and have produced a laboratory manual that is being used in neighbouring schools. The physics teacher was of the opinion that the course had not changed that much:

not many changes in physics, some of them is in order to pass the exam you have to have a certain level on investigations....most teachers do a certain level of investigations but it is not required in order to take the exam for instance. (*physics teacher*)

The chemistry teacher uses a variety of teaching methods and focuses on trying to bring the gap between theoretical chemistry and science, technology and society. In her opinion this effort is necessary to motivate students and help sustain their interest in chemistry. For this reason she was considered to be adapting the reforms. However she was not convinced of the value of datalogging:

Not me myself no, (I have not got involved in using datalogging)...I think if I wanted help, I reckon I could ask someone here. We have more or less experts on datalogging here and they also have adequate equipment in the labs. (*chemistry teacher*)

The mathematics teacher presented the problem of newer teaching methods by explaining the amount of time it would take to teach each topic for understanding:

The idea is that (they) are not supposed to (lecture for the entire class) however most maths teachers are challenged to think of other ways of teaching maths that could be effective. A lot of these alternative math teaching strategies that we have seen in Norway take a lot of time, you know, you build the model or you go out and look at architecture and the geometry of architecture something you could do in thirty minutes in the classroom is taking you two and a half hours in the field and they feel that they don't have enough time (to teach like this). (*mathematics teacher*)

Teachers are responsible for assessing their own students. The chemistry teacher uses a type of practical examination that has an oral component also:

(the examination) is both oral and practical but during this thirty minutes that you see them and talk to them they don't do the whole experiment; they have a small table with a lot of equipment and they have to explain to me how they would use it. (*chemistry teacher*)

(e) Case 1: Abel: A Summary

Abel is a large urban school with a high academic reputation. It had a regional reputation for its production of physics manuals to assist teachers with the experimental side of the subject. It has excellent organisational structures and supports for the teaching of science and mathematics: a Head of Department; a designated teacher to take charge of maintaining laboratories and resources; new laboratory designs to facilitate group work and excellent ICT facilities. The Head of Department is conscious of her pedagogical leadership role and trying to introduce the new reforms. According to the HOD, teachers, in this school, were more familiar with covering the course than teaching in new learner-centred ways. The science teachers indicated that their pre-preparation for class involved a range of strategies, including group work and experimental work. The chemistry teacher was found to be adapting the reforms, confident with student experimental work and

connecting topics to real world applications to improve student motivation. She was closely followed by the biology teacher, who as head of department, was near the tipping point and was assisting teachers change their teaching methods to suit individual need. The physics teacher and the mathematics teacher in Abel appeared more traditional. The mathematics teacher suggested that teaching for understanding might involve field-work of two and a half hours for every topic which would typically take thirty minutes using the more traditional rote learning approach. However some science and mathematics teachers in Abel were willing to experiment with change. The school has two pilot projects, in the teaching and learning of mathematics and self-directed learning. Based on Rosenholtz's (1991) criteria for the teacher as learner, especially the evaluation of pilot projects, the school is considered to be *learning enriched* and open to learning for teachers.

7.3.2 Case 2: Bohr

(a) Background and Context

Bohr is a city school with a long academic tradition. Subjects are only offered within the general studies academic area of study. Access to the school is quite competitive with many more applicants than places. This public school is classified as a medium sized school with an enrolment in the academic year 2003-2004 of 371 students. It has 36 teaching staff. The school has an extensive range of extra-curricular activities and is well supported by parents, many of whom are past pupils. In addition to the development of the well-rounded individual the school also has many years of success at getting students through matriculation and into university courses of study:

I would say first of all the school is pre-university...most of our students go through university afterward. (*head of department*)

(b) Organisational Structures and Supports

While the buildings are old they are refurbished, with stone walls, glass panels and wooden floors combining to give a restful and modern appearance. The basement has been restored as a school library, ICT facilities and a reading room. Bohr has three science laboratories and four computer rooms. They have a designated annual budget for science and one of the science teachers, with additional remuneration, has responsibility for ordering and maintaining equipment in the laboratories. There are thirteen science teachers in the school and they met twice per term. There are ten mathematics teachers and they are time-tabled to meet once per term.

(c) Perspective of Management

The principal noted that the focus of the Ministry was on quality and especially on improving quality in mathematics. They had visits from the education directorate annually and were expected to write school reports. These did not involve detailed subject evaluation. They were meant to have their written plans ready for evaluation:

We have the head of the county (education directorate) and some of his (*inspectors*) in the county administration in the school every year and they will ask for what are your plans for the next year?...They ask us for an evaluation document...We are (only) at the beginning of making documents more formal and every year we want to do for the next year. We (now) have to plan how we will address this. (*school principal*)

Students have access to an on-line questionnaire on learning and, in his opinion, they evaluate the school and their findings were published on a national web-site:

the students inspect us.....They answer over thirty questions about learning....We have got the reports for our school how the students do...and the results are published on the internet...and the exam results will all be published in the same website...when it is finished we can go into the website and we can compare the evaluation research from the exams and the research from the local directorate. (*school principal*)

This school principal does not stay remote from his students:

The students come up here and knock on the door and go in to the principal. The door is often open and that has been the trend as long as I worked here. The door has always been open and the students come up and talk to the principal (*head of department*)

The Head of Department has over 16 years experience. He is teaching for only thirty per cent of the time with seventy per cent of his time allocated to his Head of Department duties. He is involved in cross-curricular meetings with teachers in the area of teaching for differentiation, providing for individual student need.

(d) Perspective of Teachers

The school prided itself on its academic achievement and its tradition of good results and teachers were not convinced of new methodologies:

our teaching is traditional....this is the way the student gets good results.....what we see (out there) is not so good but the tradition we have here is good. (*science teacher*)

The physics and mathematics teacher had over sixteen years experience, the chemistry teacher had over twenty years and the biology teacher had over six years experience. The physics-mathematics teacher while not embracing change fully was at the tipping point of the reforms: he was using a range of teaching approaches in physics, including experiments and datalogging. He was also using web-sites and worksheets in the teaching of mathematics. In terms of assessment of physics the students keep a journal and are awarded marks based on both knowledge and skills. The biology teacher regularly uses the text-book and her most frequent teaching methods are teacher instruction and experimental work. One teacher noted the difficulty of motivating students to read deeply into a subject leading to difficulties later at university level:

(When) they go to higher education we find we have a bigger problem then. In first year in University we have 50% failure rate in some subject areas because they are crash coursing this. But they don't have the breadth. They haven't the regular, the ground work isn't there. So that's a common problem. (*physics teacher*)

The chemistry teacher was teaching for over twenty years and was very traditional and deeply sceptical of the learning reforms. He uses teacher instruction and experimental work and does not use datalogging. He suggests that the difficulty with maintaining standards is not helped by the fact that the reform in lower secondary appears to have led to a lowering of standards:

The first students who have done their Reform 97 are with us now and the teachers and the first grade are complaining that they have not the same attitudes as third year especially in mathematics....this is also a problem in teaching science in first grade. (*chemistry teacher*)

The teachers in Bohr were generally found to be not rushing to implement new methods of teaching and learning. They were embracing change very slowly and only after careful consideration of alternative proposals. Many of the reforms with respect to students taking responsibility for their own learning were being contested.

(e) Case 2: Bohr - A Summary

Bohr is a medium sized city school with a long academic tradition and many years of success at developing students in well-rounded ways as well as assisting students achieve matriculation to university. The academic focus and the history of this success seems to cast a long shadow, with both management and teachers, over the new pedagogical reforms with their emphasis on self-directed learning and differentiated teaching. The chemistry teacher was most sceptical of the learning reforms. The physics-mathematics teacher, on the other hand, was near the tipping point of the reforms and was using more learner centred approaches in both subjects. Facilities are generally very good for science and mathematics, with a head of department, one teacher designated to take care of stock in the laboratories, three laboratories, four computer rooms and scheduled teacher meetings. However while many aspects of Rosenholtz's (1991) criteria are found, a head of department, regular time-tabled meetings of teachers and access to continuing opportunities for learning there was less evidence of a questioning and an evaluation

culture among the science and mathematics teachers. The school was classified as *moderately impoverished* for developing the science and mathematics teacher as a professional learner.

7.3.3 Case 3: Franklin

(a) Background and Context

Franklin is an urban public school in the suburbs of a large town. The school is a medium-sized school with 560 students in the school year 2003-2004. They offer two academic lines a study, including the general studies course of study. The school has forty one teachers. It has a reputation as an academic institution with a strong focus on science and mathematics. The students are ambitious for higher education and many of the parents, according to the school principal, are well educated.

(b) Organisational Structures and Supports

Facilities in the school are generous and modern with ICT equipment in evidence everywhere. There are four science laboratories and three computer rooms and last year the school spent in excess of Euro 40,000 refurbishing the laboratories. The physics laboratory is interconnected to a store room, a lecture theatre and a demonstration room. The structures to support science in the school are, according to the school principal, extra resources for experiments and ten per cent extra class time. In mathematics the school provides extra resources to support differentiation and sixteen per cent extra class contact time. Datalogging is, according to the Head of Department, not so attractive to the more senior members of staff. There are eleven mathematics teachers and fifteen science teachers in the school. In terms of resources mathematics teachers have an up-to-date library of texts, mathematical models and equipment and internet access in the classroom. The Head of Department, with twenty years teaching experience, convenes meetings of the science and mathematics teachers each week for forty five minutes.

(c) Perspective of Management

Socialisation and team building with staff was a major concern of the school principal. He had on several occasions brought his entire staff abroad, to places such as Greece and Italy, as this was in his opinion *good for morale*. He divided the budget between resources and inservice days to study trips abroad:

we are fairly well off as for getting what we need for teaching...part of the budget is split into three, for science, for the social science department and for languages.....we have about 80,000 or 90,000 Kroner...we can travel if we want to for about 60,000, or we can buy equipment for about 30,000 but we can also change the amount. In July, two of the teachers, are going to Copenhagen to a worldwide mathematical conference...(this happens) every fourth year..we keep an eye that there should be a chance to do exciting and unusual things. The social science department, thirteen people, went to Turkey and Istanbul two weeks ago. (*school principal*)

He explained that the school was deeply rooted in tradition and that they were taking their time to appraise change of teaching practices:

I think it's fair to say we are really traditional in what has been working well and (while) trying new things (we are) not letting go of the foot planted on the ground. We are traditional....we do not buy all the new teaching methods...unless we have tried them first. (*school principal*)

He had overall responsibility for checking that the final marking scheme conformed with nationally agreed assessment standards:

if there is a significant difference, that teacher better have a good explanation...so we check and normally the teacher has an explanation but we have one or two science teachers who are a bit hard.....we talk about it, we look at it and talk about it.. when it's something like marking, I take that (seriously) because I feel it's important and it has to be done correctly. (*school principal*)

(d) Perspective of Teachers

The physics teacher was conscious of the emotional investment in teaching:

looking back about thirty years (ago) a teacher in physics could make his notes and use the same notes year after year. We can't do that now...we have new pupils and what is very important is that the pupils will have to follow you in your teaching and you will notice when they are not you have to have some contact to teach and you will have to make this contact work not only the first day of the year but during the whole year. You are using yourself. (*physics teacher*)

The chemistry teacher has less than five years teaching experience. He mostly relies on teacher instruction and experimentation. He explained his reluctance to go quickly with state-mandated changes and was put in the deeply sceptical category with regard to the reforms:

When the government is coming with something new I'm happy to be a slow learner. I am happy to be a slow learner so (that) while I am learning this the government has quitted it. (*chemistry teacher*)

The biology teacher has eleven years teaching experience. She uses ICT-enhanced learning, using software and web-sites, engages in a dialogue of learning with the students, which is related to the variety of assessment modes used, and teaches biology for a love of nature and meaning-making. It is for this reason that she is placed in the category for adapting the reforms:

I try to get them to see the whole picture and not just the tiny fragments. (*biology teacher*)

The mathematics teacher is male with less than five years teaching experience. He regularly uses teacher instruction, worksheets and some web-sites and was found to be close to the tipping point of adapting the reforms. Another mathematics teacher, the head of department, regards himself more as a traditional teacher:

I would call my teaching traditional, it's based on one way but of course I'm open to questions and some talk.....in the first forty five minutes I usually explain and I give examples and so on, then the students have a short break and then they try to do exercises in classes, and I think that's a good way to teach, and a lot of students are happy with it, even though several of the politicians want to make students more free and study more by themselves. (*mathematics teacher and head of department*)

Last autumn the mathematics department conducted a national experiment (research and development project) in foundation level mathematics to further the research findings on teaching and learning mathematics. The mathematics classes were delivered by a team of teachers where the ninety minute class time was divided between a lecture in the large

auditorium for thirty minutes and the students were then divided up into small groups for individual attention for the remaining hour.

The teachers working as a team identified their strengths and offered a number of choices to the students. One of the class groupings, the 1C class, was a computer-class and they used a laptop computer in every subject. Two teachers gave the lecture part of the classes while the others offered themselves as specialists: one in problem-solving, one in calculator use and another in a learning support capacity. The results from the experiment showed that this approach gave a better connection between theory and practice. *(head of department)*

Teachers need to collaborate to deliver a pre-planned programme of this nature and this offers an opportunity for the teacher to specialise:

the idea is that even the teachers specialise a little. In that teacher one, they might give a lecture, teacher two, they might be problem solving, teacher three, they could look at the subject from the point of view of maximum use of a calculator for instance and number four, maybe a lecture or two and number five, perhaps those who need special help and learning support. ...well that is the idea and the students get a plan for this for a month or two weeks....and they can choose. *(head of department)*

(e) Case 3: Franklin - A Summary

Franklin is an urban medium-sized school with 560 students and 41 teachers. The school enjoys an excellent reputation in the sciences and mathematics and the students are mostly ambitious for higher education with the strong support of well educated parents. The school has generous resources and funding for the teaching of science and mathematics with time-tabled teacher meetings each week for forty five minutes. Teachers appeared conscientious for their students' welfare and one teacher mentioned the emotional labour of teaching. The school principal and deputy principal explained that they were traditional in their approach and, while open to change, they were not rushing to embrace change. One biology teacher was clearly adapting the reforms using a range of learner-centred approaches to her teaching preparation. The physics teacher was far more traditional using teacher instruction and questioning as his main strategies. The chemistry teacher was deeply sceptical of the reforms and was of the view that they were going to change again with

the next reform. The mathematics teacher was near the tipping point of the reform and had started using a number of learner-centred approaches, including worksheets. The school was involved in a research and development project in teaching and learning mathematics in foundation year. This involved teachers pre-planning a new approach with each assigned teacher offering a different specialism. The classes were brought together for a thirty minute lecture and the following hour was given to tutorial guidance where the students' choose what they needed. This had been evaluated, by both teachers and students, and was found to give a better theory-practice connection and more individual attention to students and was been tried again. In terms of Rosenholtz's (1991) criteria for developing the teacher as a professional learner the evidence from this case study suggests that the school is a *learning enriched* school.

7.3.4 Case 4: Watson

(a) Background and Context

Watson is an urban school in a large town. The school has 603 students and is classified as a medium sized school. It has eighty four full time teachers. According to the school principal the school has a mixed intake of students and prides itself in its international profile with a special interest in promoting languages. It offers the academic general studies programme and the music, dance and drama course of study. The school is experimenting with the allocation of time for students to engage in self-directed learning. They have taken ten minutes off a number of ninety minute class periods and allocated forty minutes per week for self-directed learning. This was being evaluated, initial findings were mixed and issues were being addressed. The school is also involved in a local mathematics project, in the first year of its three year cycle, with schools in two neighbouring counties.

(b) Organisational Structures and Supports

The school has three ICT rooms and three science laboratories with an adjacent preparation room. Internet access is available in the computer rooms while it was not yet available in the older laboratories. The science laboratories had been designed in the nineteen seventies and were considered to be outdated. They were considering new laboratory designs and were attracted to the concept of combining theory and practice in a type of science laboratory that was sub-divided into an auditorium part for the lecture and an oratory part for the practical work. The science budget varied from year to year and was typically in the region of Kroner 50,000. Some teachers were evaluating their pilot project on self-directed learning.

(c) Perspective of Management

The principal explained that Reform-94 was not such a big change for the school as it had been one of the pilot schools for the reform. However he explained that the main reforms were pedagogical reforms but that these had not managed to get fully into the life of the school and lead to change of practice:

what are the changes...it is in the subjects, they have changed (somewhat) and the way of teaching should be changing but I think that hasn't been taken serious enough, that is the main criticism through the reform, it hasn't got into the life of the school enough. (*school principal*)

The school has made an investment to develop the concept of self-directed learning but their efforts are not all successful and they are finding challenges. The constraints appear to be related to the differences between students motivation to learn:

what we have been more concerned about is, to have effort and worth in these study lessons, but we haven't succeeded for all of them...more about how to study at the beginning of the year, that is what we have decided to do, but we have also decided to become more serious, to follow them up in these lessons...there is always some pupil that works very well, but there are some who don't. (*school principal*)

The head of department was in the position for three years. She explained that the teachers, science and mathematics, are used to team work:

we have been planning together for many years, for about ten years I think....we have planned together and it's very good...we can do some work for each other so everybody doesn't need to do the same work. (*head of department*)

(d) Perspective of Teachers

There were seventeen science and mathematics teachers in the school and they met about twice a month for approximately an hour. The teachers in this part of the study varied from a physics teacher with over fifteen years teaching experience, a chemistry and biology teacher with over twenty five years experience and a mathematics teacher with over thirty years teaching experience. The physics teacher noted that the recent text-books were multi-media and included web-links and simulations. In her teaching she was able demonstrate the workings of a motor using both an actual model and a virtual demonstration from one of the text-books. She taught physics using a variety of teaching approaches, brought students outdoors each year for an astronomy field-trip and connected the subject to possible careers in physics. In addition she evaluated the subject, on an ongoing basis, and it for this reason she is placed in the category of adapting the reforms. Generally the school is out of date with datalogging. The new examinations in physics were emphasising a more open style of questions:

I would prefer multiple choice tests...all these open exercises are very good, they're very good for the students but for me they are hell on earth..I have to go through all the calculations because they choose different numbers. (*physics teacher*)

The chemistry teacher in this study was also the biology teacher. In his opinion reforms have made chemistry more accessible with less theory and calculations, more applications and some biochemistry. Experiments are a key feature of teaching chemistry. Students have to write these up to connect the theory with the practical and afterward this forms part of the assessment process.

(we have) practical(s) every week in chemistry and the pupils often work on....I'm supervising them ..they work in groups a lot...I give some instructions...I tell the students you have to do experiments in science..I like (the practical work), I think it's exciting...I see it works, the pupils like it...and they have to write (it up) afterwards, they have to learn the theory. (*chemistry teacher*)

He found differentiation challenging in practice:

(differentiation) looks very nice on the paper, but in many cases it's not so easy really to do it because sometimes...so if you have a big class of thirty pupils you are on your own, it might be a bit difficult to really do as it is meant to be done..well it's good that the laws are like they are...but to really do it (in practice), it's a bit difficult, and we try it, we talk about it and we try to find ways to do it. (*chemistry teacher*)

The new biology course has an emphasis on ecology, genetics and biotechnology.

Students left the schools for a few days when conducting their field-studies:

we have excursions where we study (out of school) for three days and we stay in a tent. Recently, we went to the animals in the National Park..it was very interesting, we had discussions in the evening about wildlife, where they live, bears, brown bears, lynx...we've also been to a lake where we did some fishing with nets just to see what kind of fish...we were allowed special permission to fish. (*biology teacher*)

This chemistry-biology teacher, while contesting aspects of the reforms, was at the tipping point of ownership of learner-centred approaches. The mathematics teacher lectures fifty students in the first part of the class and they then move into smaller class groups where they receive more individual attention:

I present an important topic to them and they are supposed to take notes and after that they do their exercises on the individual support but largely mathematics education is individual supervision, they help each other...I try to put the good students together and students that don't achieve that much together because they at the same level, they can inspire each other. (*mathematics teacher*)

He was traditional in his approach and questioned the freedom of choice advocated for students, as in his opinion, some students required more guidance than others.

(e) Case 4: Watson - A Summary

Watson is an urban school in a large town with over 600 students and eighty four teachers.

The school has a mixed intake and offers two academic courses of study, the general

studies course and music, dance and drama. It seeks to retain its international profile and its commitment to language teaching. The school is involved in a pilot study to promote self-directed learning. Time is made available for students each week to engage in this but it is only the already high achieving and mature students that appear to be benefiting so far. Evaluations were being conducted with students and teachers and different ways of doing this, more supervised study, is being designed for next year. The school was also involved in a local pilot mathematics project with schools in two other counties. These pilot studies were seeking pedagogical change and the teachers were in the process of evaluating these.

The school has a Head of Department for science and mathematics, an annual budget and regular time-tabled meetings for teachers. Facilities in the older science laboratories are minimal but the school is about to invest in a complete redesign of this. The school had been involved in piloting Reform-94 and teachers are familiar with planning but the management and teachers indicate a number of challenges with regard to the pedagogical reforms. For example, *differentiation* is often difficult in practice, especially if the teacher has to cope with big class groupings. The physics teacher uses multi-media simulations, a variety of teaching methods including astronomy field-trips and carries out regular evaluations with her students. It is for this latter reason that she was placed in the adapting the reforms category. The chemistry-biology teacher was using a range of teaching approaches and while contesting the reforms was clearly nearing the tipping point of taking ownership of them. The mathematics teacher uses teacher instruction and web-sites. According to Rosenholtz's (1991) criteria Watson, due to its willingness to begin the development of an evaluation culture, is found to be *learning enriched* in terms of opportunities for science and mathematics teachers to learn.

7.3.5 Case 5: Curie

(a) Background and Context

Curie is a public school in a rural setting. It is a medium sized school with 507 students. There are eighty seven teaching staff. The school has a mixed intake and offers a full comprehensive range of courses of study. In addition to the academic line of general studies the school offers an extensive range of vocational lines, including carpentry, plumbing, painting, fishery sciences and health and social sciences. This offers extensive funding and resources to the school but also many challenges. Practical classes are limited to fifteen students while theoretical classes may have up to thirty students. The school is trying to cope with a far broader range of ability than is found in a school with only one or two courses of study.

(b) Organisational Structures and Supports

The science, mathematics and technology teachers form one department in this school and they meet as a group and as separate groupings on several occasions per month:

we have meetings approximately once a month that are all the maths, science and computer science teachers meeting together, and then in addition we meet less formally as science teachers in addition to that maybe once a month. So twice a month we have that contact. (*head of department*)

One teacher, besides the head of department, has responsibility for ordering and stock taking in the laboratories:

there's one teacher, he happens to be a biology teacher, who has as a part of his job, responsibility for buying in the equipment that we need in the labs, and making sure that the supplies are where they're supposed to be and the chemicals are Ok. (*head of department*)

The group has a head of department, and generous funding for these MST subject areas.

The two science laboratories, in the academic course of study, are set apart by a large preparation room with separate access and space for teachers to study or prepare experimental work. One modern laboratory has a tiered lecture style auditorium in the

same room as the experimental work space. Another laboratory had *space age* ducting with a network of interconnecting large pipes across the ceiling descending to individual fume hoods that may be pulled down over each experiment as required. All laboratories have internet connection. Each student purchases a graphic calculator for mathematics classes. The school has excellent staff facilities with staff housed together in a separate wing of the building, with a staff room, reading area and full kitchen facilities all in bright wood with modern furniture. There are seven science and seven mathematics teachers in the school. They have not conducted a formal evaluation of their programme. The inservice courses offered through the county education directorate are generic as well as subject-related:

There are different courses offered in the sciences to keep us up to date..I've been to courses (this year) but not in the sciences, I've been to courses in hyperactivity and mental health, those types of things. (*science teacher*)

(c) Perspective of Management

The Deputy Principal spoke of the ongoing need to regularly liaise with external agencies and the challenge to develop the students to take more responsibility for their own learning. She favoured more self-assessment by the students to build their assessment for learning in more formative ways:

We want to involve the students more in their own learning and we would like to get them interested in more self-assessment. (*deputy principal*)

The school is currently experimenting with a study hour per week for each student where they engage in some independent learning:

Our teachers are very caring and we find that teachers are (increasingly) fed up with changes and being asked to continually change. (*deputy principal*)

The teachers also admitted that they were quite *weary of reform* and being asked to change. The self-directed learning project is being conducted on an experimental and

researching the promotion of learning through time-tabling students for time to study on their own. The findings are due to be evaluated.

(d) Perspective of Teachers

The teachers found trying to motivate students to take responsibility for their own learning their greatest challenge. This was at the heart of the pedagogical reforms, the new role of the teacher as planning partner with students and facilitator rather than driver of learning.

Teachers generally work together using a team approach:

We meet everyday. We sit in the same rooms and we do a lot of co-operating all the time, so we all come in and we co-operate with arranging tests, making results, correcting for each other, discussing themes within the legislation. (*mathematics teacher*)

The teachers have varying years of teaching experience, the physics teacher has over six years, the chemistry teacher has over twenty years, the biology teacher has over nine years and the mathematics teacher has over eleven years teaching experience. The chemistry teacher is fully conversant with datalogging and willingly assists the other science teachers as required. They draw on a range of teaching strategies including teacher instruction, experimental work and field-trips. The biology teacher uses web-sites and sometimes datalogging equipment. She has older students who are making up hours to proceed to the academic line from the vocational lines:

all the 1st year students are required to take general science and (I have) students that have gone to vocational lines previously and now are coming back to get the general study requirements to go on to university or college, and I have those students as well, and those are older students, many of them are 19, 20, 21 years old, and they also require them to take more general science. (*biology teacher*)

She divides the class into three to four groups and uses a problem-solving approach which, in her opinion, promotes critical thinking. In her classroom teaching, in her opinion, she varied her time at the board with most of her time spent in among the students. This learner-centred approach singled her out as adapting the reforms:

In biology I combine working at the board with a lot of group work on problem solving, and I think the problem solving is maybe almost three quarters of the time and it's usually in groups and the one quarter of the time is working at the board, and then in addition we have some excursions, some field work and then some special project work where we use the internet, but it's primarily group problem solving and working at the board. (*biology teacher*)

Assessment of science and mathematics is both by the school and the state. For example, the biology teacher assesses the second year biology class using a variety of modes, including oral assessment, written testing and experimental testing. She has an emphasis on preparing for the oral examination with her current students:

a third of it is based on their lab work and then the other two thirds is primarily testing, and the testing I've done has mainly been oral testing, and the level that I'm teaching now is if they get taken up for the state exam it's only an oral exam so I do more oral testing than written testing but each semester they have had one written test as well. (*biology teacher*)

The mathematics teacher has mathematics instruments, text-books and graphic calculators for the teaching of the subject. She finds the course long and it is often difficult to find time to teach using a problem-solving approach. She describes her style of teaching as a mixture of methods, she uses teacher instruction, more than she would like, and also pair work and group work. She likes to facilitate differentiated learning and have students help one another and for this reason she was also found to be adapting the reforms:

I find myself ending up doing more teaching in front of the students than I ideally like to do because I have this idea of them also finding out things for themselves, but this of course is a little different according to each class, I have to say some of them are very independent and are able to find out a lot of things on their own, and I spend at least half of the time in all the classes just walking around and helping each person or each group individually. (*mathematics teacher*)

Her method of assessment was predominantly by written tests and when there was a grade in discretion she used co-operation in class as a guideline filter:

I do base my grades also on speaking to each individual in class. I keep asking them questions when I help them so I get a very good idea from day to day of what they're capable of. So this is of course more informal...I have to admit that the main thing that I base my grades on are these written tests, and the oral idea I get and also what they do in their work in class, how they help each other, all those things, it comes in addition to it when I'm in doubt. (*mathematics teacher*)

(e) Case 5: Curie - A Summary

Curie is a rural public school with over 500 students and 87 teachers. It offers an extensive comprehensive curriculum with many vocational courses of specialist study as well as the general academic course of study. The students are a mixed cohort and would have a far broader span of academic achievement than would be found in a school offering only one or two courses of study, especially academic courses of study. They offered more extensive pathways than most upper secondary schools and sometimes have older students returning to academic studies from vocational studies through making up hours in general science or mathematics. The science and mathematics teachers have excellent facilities and a head of department, regular time-tabled meetings and a generous budget. They have two state-of-the-art science laboratories separated by a large preparation room for teachers to prepare for class or to prepare experiments in advance. While the physics teacher is more traditional in approach the chemistry teacher assists colleagues with datalogging. The biology teacher makes use of group work and problem-solving approaches to develop critical thinking and, for this reason, was regarded as adapting the reforms. The mathematics teacher was also adapting the reforms, supplementing her teacher instruction with individual and group work and learner-centred approaches. Oral work in science is an important assessment component and the biology teacher explains that this was the component she was mostly preparing her classes for this term. The teachers have not yet developed a culture of evaluating their science and mathematics programmes formally. They had just started a pilot project on self-directed learning. According to Rosenholtz's (1991) criteria for the development of the teacher as professional learner this researcher places the school as *learning enriched* based mostly on their experimental approach to teaching for the promotion of learning with a diverse range of student intake.

7.4 Numerical Data from the Case Study Schools

The case study schools provided data for the graduation of their students in science and mathematics across the three years of the upper secondary cycle, from foundation year to advanced I and advanced II in the second and final year (Table 7.3 to Table 7.9). Data was also compiled with respect to the number of science and mathematics teachers and their structural arrangements and budgets for science and mathematics (Table 7.10). Finally data was compiled from each of the teacher profiles giving their primary degree subject, their years of experience and any higher degree qualifications (Table 7.11). Analysis of the graduation data from these schools, Table 7.3 to Table 7.9, shows a number of interesting observations: of the students in foundation year, with the exception of Franklin and Abel, there was a strong fall off in the spring of first year in the number of students remaining with the more theoretical course in mathematics. There was a strong fall off in the number of students progressing to advanced level in physics, chemistry and biology. Physics held the largest numbers in all schools unlike the pattern in Ireland. The pattern for Biology was very different in Norway with a far poorer uptake than in Ireland. As students progressed to the third year of specialisation there was again a marked fall-off in uptake at all the advanced levels. For example, in Franklin with 193 students taking foundation year in science, 102 students choose second year physics (2FY) and only 55 of these completed the third year of specialisation (3FY).

Both science and mathematics departments, in these five case study schools, ranged in size from seven teachers to seventeen teachers respectively (Table 7.10). All science and mathematics teachers, in these five case study schools, had formal time-tabled opportunities to meet during the school day in schools in Norway. The number of meetings varied from weekly time-tabled meetings of forty five minutes, to ten meetings per year to two meetings of one to two hours per month for the science and mathematics

teachers. These meetings were in addition to the general staff meetings held on a regular basis in the schools.

The qualifications of teachers in this study were considered from the perspective of the subject specialism in their primary degree and any higher qualifications they might possess (Table 7.11). It was found that twelve teachers of the twenty teachers involved in the study were qualified in the subject they were teaching. The eight teachers that were not qualified in their subject included two physics teachers, two chemistry teachers, one biology teacher and three mathematics teachers. Twelve out of twenty teachers had higher degrees. These teacher profiles raise concerns about qualification of mathematics teachers.

Table 7.3 Graduation in natural science (*naturfag*) in the case study schools 2003-2004.

School	Natural Science		
	Total	Male	Female
Abel	235	87	148
Bohr	126	50	76
Franklin	193	93	100
Watson	213	101	112
Curie	317	183	134

Table 7.4 Graduation in mathematics in foundation year (1MX), 2003-2004.

School	Total (1MX)	Male	Female
Abel	187	70	117
Bohr	95	40	55
Franklin	146	82	64
Watson	98	54	44
Curie	45	27	18

Table 7.5 Graduation in physics in advanced level I and advanced level II (2FY, 3FY) in the general studies programme, *allmenne, økonomiske og administrative fag*, 2003-2004.

School	2FY	2FY	2FY	3FY	3FY	3FY
	Total	Male	Female	Total	Male	Female
Abel	67	48	19	50	31	19
Bohr	67	36	31	33	21	12
Franklin	102	70	32	55	41	14
Watson	55	32	23	21	17	4
Curie	59	33	26	18	10	8

Table 7.6 Graduation in chemistry in advanced level I and advanced level II (2KJ, 3KJ) in the general studies programme, *allmenne, økonomiske og administrative fag*, 2003-2004.

School	2KJ	2KJ	2KJ	3KJ	3KJ	3KJ
	Total	Male	Female	Total	Male	Female
Abel	30	15	15	41	22	19
Bohr	49	27	22	33	16	17
Franklin	75	37	38	36	18	18
Watson	46	20	26	28	12	16
Curie	22	9	13	16	7	9

Table 7.7 Graduation in biology in advanced level I and advanced level II (2BI, 3BI) in the general studies programme, *allmenne, økonomiske og administrative fag*, 2003-2004.

School	2BI	2BI	2BI	3BI	3BI	3BI
	Total	Male	Female	Total	Male	Female
Abel	42	19	23	25	9	16
Bohr	48	9	39	39	11	28
Franklin	48	9	39	24	4	20
Watson	46	21	25	14	4	10
Curie	18	6	12	23	8	15

Table 7.8 Graduation in mathematics in advanced level I and advanced level II (2MX, 3MX) in the general studies programme, *allmenne, økonomiske og administrative fag*, 2003-2004.

School	2MX	2MX	2MX	3MX	3MX	3MX
	Total	Male	Female	Total	Male	Female
Abel	72	40	32	62	33	29
Bohr	69	35	34	53	27	26
Franklin	125	77	48	89	56	33
Watson	55	28	27	27	20	7
Curie	45	20	25	16	10	6

Table 7.9 Graduation in mathematics in advanced level I and advanced level II (2MZ, 3MZ) in the general studies programme, *allmenne, økonomiske og administrative fag*, 2003-2004.

School	2MZ	2MZ	2MZ	3MZ	3MZ	3MZ
	Total	Male	Female	Total	Male	Female
Abel	46	27	19	38	15	23
Bohr	22	1	21	29	7	22
Franklin	28	9	19	16	3	13
Watson	55	27	28	13	7	6
Curie	8	4	4	3	2	1

Table 7.10 Structures for science and mathematics teachers in the case study schools 2003-2004.

School	Number of Science Teachers	Time allocated to meeting	Frequency of Meeting	Number of Mathematics Teachers	Time allocated to meeting	Frequency of Meeting
Abel	17	One and a half hours	Ten times per year	17	One and a half hours	Ten times per year
Bohr	13	45 minutes	Two meetings per week	9	35 minutes	One meeting per week
Franklin	14	45 minutes	per week	9	45 minutes	per month
Watson	7	One hour	Twice per month	10	1-2 hours	per month
Curie	7	One hour	per month	7	One hour	per month

Table 7.11 Teacher qualifications and experience in the case study schools in Norway.

Subject	Years of Experience	Primary Degree Subject	Higher Degree
Physics	14 Years	Physics	Psychology
Physics	20 years	Mathematics	Masters ICT
Physics	30 years	Not stated	Not stated
Physics	16 years	Physics	Masters of Science
Physics	10 years	Physics	None
Chemistry	9 years	Chemistry	Masters in Chemistry
Chemistry	22 years	Physics	None
Chemistry	9 years	Chemistry	None
Chemistry	25 years	Mathematics	Masters in Chemistry
Chemistry	20 years	Chemistry	Physics
Biology	15 years	Biology	Masters in Education Masters in School Administration
Biology	10 years	Biology	Masters in Education
Biology	11 years	Biology	None
Biology	25 years	Mathematics	Masters in Chemistry
Biology	11 years	Biology	Doctorate (candidate)
Mathematics	14 years	Physics	Psychology
Mathematics	20 years	Mathematics	Masters ICT
Mathematics	4 years	Mathematics	Masters Mathematics
Mathematics	31 years	Zoology	Masters in Science
Mathematics	15 years	Geology	None

7.5 Cross-Case Synthesis of the Case Study Schools

Four of out five school managements – Abel, Bohr, Franklin and Watson – mentioned their academic tradition with Bohr specifically mentioning university expectation for its students. Senior management relied on their middle management team for day-to-day management of the school. These Heads of Department had serious responsibility for convening subject teacher meetings, taking responsibility for the maintenance of the laboratories and paying for inservice courses. Two HODs – Abel and Bohr – mentioned their need to discuss differentiation with teachers. The HOD of Abel clarified that many good teachers in her school were traditional and conservative. Four of the five case study schools were engaged in 2003-2004 in local and national pilot research and development studies, referred to locally as experiments, in promoting self-directed learning and teaching and learning mathematics. Various permutations were being tried and tested.

In this multiple case study research management appeared conscious of the reforms being about pedagogical changes. Management in Watson put the perceived success rate of these pedagogical reforms in context when he explained that their school had been involved in the pre-reform 1994 pilot study, while the changes still had not get fully into the life of the school. Learning centres approaches were providing a high level of challenge to traditional inherited practices. A chain of evidence was found, with twenty one voices from a total of thirty voices, contesting the reforms (Table 7.12). Five teachers were adapting the reforms – a chemistry teacher in Bohr, a biology teacher in Franklin, a physics teacher in Watson, a biology and a mathematics teacher in Curie. Two chemistry teachers – in Bohr and Franklin - were deeply sceptical of the reforms.

The science teachers in the study indicated that teacher instruction, questioning and experimental work were their preferred teaching approaches. They occasionally used a number of other methods including group work and field-trips. Datalogging was generally

not being used frequently in these case study schools. The science teachers adapting the reforms were using learner-centred approaches to their classroom preparation. Mathematics teachers most frequently reported using teacher instruction and questioning as their main teaching approach (Table 7.13). Two teachers frequently used worksheets while one teacher occasionally used computers in the teaching of mathematics. Three additional teachers were close to the tipping point of taking ownership of the reforms – a biology teacher in Abel, a mathematics teacher in Franklin and a chemistry-biology teacher in Watson. None of the case study schools were involved in a formal evaluation of their science or mathematics courses of study.

Table 7.12 The extent of adaptation and contestation of the reform policies.

School	+1	0	-1	-2
Abel	1	1	4	0
Bohr	0	1	4	1
Franklin	1	0	4	1
Watson	1	1	4	0
Curie	2	0	4	0

Assessment, in these case study schools, was both school-based and by state examination. The teachers engaged in marking conferences in the schools with the school principal ensuring standards were maintained. For example, data from Bohr show the percentage of students taking external oral and written examinations in Table 7.14. It may be seen that in general only approximately 10 to 20% of students take these state examinations.

Finally when searching for rival explanations to understand the raw data in this study it is clear that while effort and energy is being spent in introducing new pedagogical practices, that seek to develop a culture of teaching for learning, there is something at school-level blocking the full adaptation of these reforms. The block, in Norway, is not organisational and structural as the majority of these schools have very good to excellent conditions. The traditional mind-set of management and the essentialist epistemologies of teachers appears

to be a significant factor in this blockage. Nineteen out of the twenty teachers in these case study schools indicated that they had not taken part in a formal evaluation of their science or mathematics courses of study. The physics teacher in Watson was the exception. The majority of case study schools in this study – Abel, Franklin, Watson and Curie – were regarded as *learning enriched*, according to Rosenholtz’s (1991) criteria for the development of the teacher, as a professional learner. Due to systemic reforms they all had formal structures for communication pathways between management-teachers and teacher-teachers. However, they all varied in the extent to which they had engaged with developing a culture of evaluation. This was an area that schools appeared to need considerable support and further knowledge. Hargreaves and Goodson’s (1996) model of the *post-modern professional* seems too far advanced when compared with findings from this exploratory study. Their *flexible model of teacher professionalism* appears more appropriate to this study.

Table 7.13 Teaching methods used by mathematics teachers.

Approach	Frequently	Occasionally	Rarely	Never
Pair Work	1	0	2	0
Questioning	3	0	1	1
Logic Puzzles	0	0	0	2
Worksheets	2	0	1	0
Use of Computers	0	1	2	0
Project Work	0	1	2	0
Teacher Instruction	5	0	0	0
Field-Trip Outdoors	0	0	0	3

7.6 Chapter Seven: Summary

While *Abel*, *Franklin* and *Watson* offered two academic courses of study, *Bohr* only offered one academic course and *Curie* offered an extensive range of vocational and academic lines. Schools that perceived themselves as offering safe passage to university, *Abel*, *Bohr* and *Franklin*, all mentioned strong parental support and high expectations. The evidence from Chapter Seven is now reflected through revisiting the research questions.

Table 7.14 School examinations and external examinations, oral and written examinations, in Bohr, 2003- 2004.

Bohr	School Examination	External Examination	External Examination
	TOTAL	Oral	Written
Physics			
2FY	67	12	0
3FY	33	5	14
Chemistry			
2KJ	49	6	0
3KJ	33	6	7
Biology			
2BI	48	-	-
3BI	39	5	16
Mathematics			
1MX	95	0	16
1MY	31	0	9
2MX	69	0	20
2MZ	22	0	12
3MX	53	12	18
3MZ	29	0	9

Q1. What can be learned from a study of the micro policy process in 2003-2004?

The management and teachers in this study were conscious that the changes expected of them, in the science and mathematics reforms, were mostly concerned with pedagogical changes. They were expected to engage in *adapted teaching* where teaching and learning was differentiated for individual need. The development of this culture of learning was perceived in Abel as challenging teachers' need *to cover the course*. In Bohr, management and teachers were proud of their long academic tradition and were only *embracing change slowly*. In Franklin, while a number of changes of practice were being piloted and evaluated, they were according to the school principal *a traditional school*. In Watson the principal explained that while there was a recognition that changes were about new teaching methods - and the school had been one of the Reform 1994 pilot schools - these reforms had not yet got into *the life of the school*. In Curie, teachers *had grown weary of*

being continually asked to change and were finding it difficult to challenge teenagers to become self-directed learners.

It is clear that the pedagogical reforms, accompanying the curricular reforms in science and mathematics, were challenging the mind-set of both management and teachers in these case study schools. While five teachers were adapting the reforms - a chemistry teacher in Bohr, a biology teacher in Franklin, a physics teacher in Watson, a biology teacher and a mathematics teacher in Curie - the majority of management and teachers were contesting the reforms. The level of contestation, twenty one respondents from a total of thirty voices, led to a chain of evidence from school to school (Table 7.12). This replication trend was challenging policymakers to reconsider the extent to which public schools could fulfil their moral obligation to help students achieve access to higher education on the one hand and take time, on the other hand, to facilitate a new culture of teaching for learning.

Q2. How are the policy reforms being adapted inside the schools through changes in school organizational supports and structures in 2003-2004?

These five case study schools were consistent in their infrastructure and supports for science and mathematics reforms. A range of facilities and resources were found to assist the teacher use a variety of learning approaches. In three of the five schools there were modern state-of-the-art laboratories redesigned to assist team work and blend theory and practice. These changes cost in the region of Euro 40,000 to 200,000 per school. Another school was about to change its laboratory designs. There was one designated teacher, in each school, with responsibility for upkeep of the laboratories. They received a small stipend for this work. They all had budgets, in the order of approximately Euro 7,000 to Euro15,000 per annum, for science and mathematics resources, inservice courses and, in the case of Franklin, for attending international conferences. Structural reforms, implemented through national policy, ensured that there was a head of department for

science and mathematics, in each of the case study schools, with responsibility for convening meetings of the teachers, managing the budget and paying the county authorities for inservice courses. The post had considerably reduced teaching hours to assist this work (30% teaching). In addition schools had generous ICT facilities and datalogging equipment.

Q3. How are the policy reforms being perceived inside the schools by management in 2003-2004?

Management perceived that the policy reforms in science and mathematics as being mostly about pedagogical reforms. The principal in Franklin explained that they were traditional and were not willing to buy into new teaching and learning methods without first having tried and tested them. The principal in Watson explain that their school had been one of the pilot schools for Reform-1994 and that new teaching and learning approaches had not got into the daily life of the school. Management in Bohr defended their traditional inherited success at getting students into university education. By contrast the head of department in Abel was aware of her pedagogical leadership role and was supporting teachers change their teaching approaches. She also noted that many of her good teachers, traditional and conservative in her opinion, were due to retire and would be experienced as a big loss to the school. The deputy principal in Curie explained the investment they were making to develop self-directed learning among a large diverse population of students.

Q4. How are the policy reforms being perceived inside the schools by teachers in 2003-2004?

The pedagogical reforms, in science and mathematics, made learning the cornerstone of Reform-94. They promoted self-directed learning, differentiated teaching, students and teachers working together as planning partners and changed the role of the teacher as lead instructor and subject expert to facilitator of leaning. While teachers claimed they used a

range of teaching methodologies they did not perceive themselves as facilitators of learning. They relied on teacher instruction as their most frequently used teaching approach. However this was supplemented by a range of other approaches, including experimental work and pair work. Many described themselves as *traditional* and explained that their style of teaching was generally different from what policymakers wanted. However five teachers, four science teachers and one mathematics teacher, were adapting the reforms and had changed their focus more toward student's learning needs. There was also evidence of a number of additional teachers in the study, the chemistry-biology teacher in Watson and the biology teacher in Abel who were close to the tipping point in terms of adapting the reforms. At the other end of the spectrum two chemistry teachers, in the study, were deeply sceptical of the reforms. All science and mathematics teachers, in this study, were involved in assessing their own students, in written, oral and practical work, and attending school-based marking conferences with the principal and colleagues to maintain national standards.

Teaching as a professional praxis required, at a minimum, collaboration with management and colleagues and development of a culture of evaluation. The culture of evaluation with science and mathematics teachers, in this study, was not well developed. While there was some evidence of evaluation of pilot studies there was no evidence of evaluation practices with respect to every-day science and mathematics courses. Nineteen out of twenty teachers indicated that they were not involved in a formal evaluation of their course of study. The physics teacher in Watson was the exception.

Q5. What can be learned from a study of a range of quantitative findings including teacher profiles and uptake in the sciences and mathematics in 2003-2004?

Uptake in the sciences and mathematics, relative to the sizes of the schools, compared favourably with national statistics. The schools show a high fall off pattern in more

theoretical mathematics by as early as spring of first year and there was also a high fall off in students progressing to take advanced II specialisation in physics, chemistry and biology in the final year. Physics uptake was more popular than biology, one explanation given was that biology did not count for matriculation. Eight teachers, in this study, were teaching subjects that they were not qualified in while the number of teachers with higher degrees, twelve teachers out of twenty teachers, suggested a reasonable academic capital. The teacher profiles raised concerns about the qualification of mathematics teachers. This needed further research study.

Chapter 8: Comparative Analysis, Findings and Recommendations

8.1 Introduction

This research study, beginning with the theoretical framework and research questions, seeks to illuminate the education policy process through a cross-national comparative research study between Ireland and Norway. The study investigates the reforms in science and mathematics in upper secondary academic education through a range of lenses examining the research questions posed. Evidence was sourced in an archival study of official policy documents, over a forty five year timeframe, and an exploratory case study research in ten schools in 2003-2004, five in each country. The long timeframe in the macro policy study gives a thicker historical description of the reform impulses in these subject areas, and helps identify similarities and differences between both countries in this regard. The micro-level study explores the mutual adaptation of the policy reforms at one snap-shot in time through the perspective of management and teachers.

The reliability and validity of this evidence is fully supported through a wide range of triangulation and validation criteria and tests. In this study the five criteria for validating qualitative research by Smith (1996) - *internal coherence, presentation of evidence, independent audit, triangulation and member validation* - and the four tests advocated by Yin (2003) - *construct validity, internal validity, external validity and reliability* - were all used to guide this aspect of the study and give quality assurance and rigor to the findings.^{1,2} These tests and criteria included using a range of lenses to triangulate multiple perspectives, having a theoretical framework, using multiple sources of evidence, cross-checking data with respondents and schools, having key informants review drafts of the case report, pattern-building and searching for rival explanations. These are all dealt with in greater detail in Chapter 3, Section 3.6. Turning evidence into a claim to knowledge and research findings involves a process of interweaving evidence with theory and argument.

This is the main purpose of this final chapter. Yin's (2003) criteria for high quality analysis includes three main features: that all evidence is attended to, that it addresses the most significant aspect of the study and that the researcher makes full use of their expert knowledge.³ In this chapter we will revisit the theoretical framework and research questions and use these, together with the archive and case study evidence, to reflect on the findings and make some recommendations.

8.2 Revisiting the Theoretical Framework and Key Research Questions

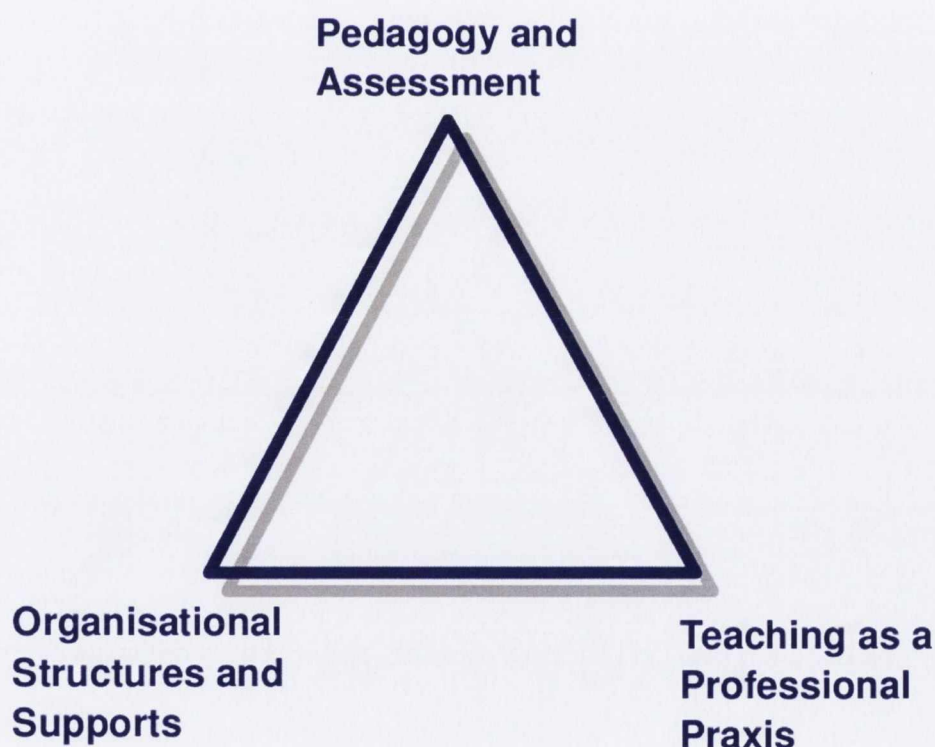
The study is underpinned by a novel conceptual framework, devised by the author, and includes the exploration of three sub-themes all inter-related through the new paradigm of teaching for learning in science and mathematics upper secondary education. It considers *curriculum as institutional and cross-national text* and explores this as *policy as text* and *policy as professional praxis*. Within these landscapes the substantive dimensions explores the *organizational and process dimensions*. Inside the school the *mutual adaptation model* of curriculum reform was used. Within this framework, adapted from research findings of Pinar et al (2002), Bowe, Ball and Gold (1992), O'Buachalla (1988) and Snyder, Bolin and Zumwalt (1992), three sub-themes emerged.^{4,7} These sub-themes includes pedagogy and assessment, organisational structures and supports and teaching as a professional praxis (Figure 8.1). These three sub-themes are stated as follows:

- **Pedagogy and Assessment:** This sub-theme considers the pedagogical practices recommended in the reforms in science and mathematics upper secondary academic education. It is related to teachers' everyday work and inextricably links teaching, learning and assessment for the development of a culture of learning.
- **Organisational Structures and Supports:** This sub-theme suggests that the new learning paradigm, recommended in the science and mathematics reforms, requires

different organisational structures and supports at the level of the school – facilities, resources, teacher-teacher meetings times – than was required for previous reforms that supported more teacher-centred forms of schooling.

- **Teaching as a Professional Praxis:** This sub-theme regards the teacher as a professional learner, within a post-modern conception of the teacher as professional, and recognises the need for teacher collaboration, pre-preparation for teaching for individual need, teacher evaluation, both self-evaluation and peer evaluation, and opportunities for teacher continuing learning and education.

Figure 8.1 The three sub-themes underpinning the research study.



Source: Author.

The six key questions driving both macro- and micro- levels of the study, in both countries, now need to be revisited in order to reflect on the findings:

- Q1. What can be learned from a historical study of the macro policy process and from a study of the micro policy process in 2003-2004?
- Q2. How were the reforms in school organizational structures and supports changed between 1960 and 2005 and how were these refracted inside the schools in 2003-2004?
- Q3. How were the key curricular and pedagogical reform waves in science and mathematics education changed in the 1960-2005 time-frame?
- Q4. What was the changing role of the teacher and changing opportunities for continuing professional learning in the 1960-2005 time-frame?
- Q5. How were these policy reforms, in science and mathematics, perceived inside the schools by management and teachers in 2003-2004?
- Q6. What can be learned from a study of the graduation rates in science and mathematics and the changing number of schools and teachers at national level and the school profile, teacher profiles and uptake in the sciences and mathematics in 2003-2004 in the case study schools?

8.3 How does the numerical data from each country inform the study?

Despite the major structural investment in Norway both countries show a decline in the physical sciences and mathematics uptake patterns from 1994 to 2005. Both countries had mid-range results from PISA (2000, 2003) in science and mathematics literacy with Ireland somewhat ahead in both international studies. Ireland was also ahead in terms of the graduation numbers in mathematics, biology and chemistry in senior cycle. Norway retained the edge with respect to physics uptake. Policy directives in education in Norway, such as improving the experimental nature of the subject, using datalogging to enhance the experimental work, and having a second assessment component in each subject area had not of themselves, from 1994 to 2005, led to an increase in the uptake of the physical sciences or the more theoretical courses of study in mathematics.

The number of students graduating in science and mathematics in *Leaving Certificate (established)*, from 1960 to 2005, alongside the total cohort is given in detail in Chapter

Four and in a summary table in this chapter, Table 8.1. It may be seen that the physical sciences, physics and chemistry, remained at less than 20% uptake throughout the entire period of research. Physics started at 12.8% in 1960 and grew to a high of 19.2% by 1984 and levelled off to 14.6% by 2005. Chemistry started at 14.8% in 1960 and grew to a high of 19.8% by 1984 and leveled off at 16% by 2005. Biology retained its popularity growing from 43.9% of the student cohort in 1971 to 52.8% in 2005.

Table 8.1 Total number of students graduating in LC and in LC science and mathematics 1960-2005.

Year	LC (total)	Physics	Chemistry	Biology	Maths (total)	Maths (higher)
1960	7,966	1,021	1,178	-----	7,076	1,155
1970	18,975	2,607	3,613	-----	15,521	2,128
1980	36,539	5,102	6,984	19,309	34,830	3,308
1990	55,146	10,515	8,706	27,080	52,972	6,767
2000	60,737	8,588	6,711	26,660	58,705	10,645
2005	54,073	7,939	8,633	25,360	52,178	9,841

Less than half of the students in upper secondary education in Norway follow the academic line of study. However comparable numbers of students, between the countries, graduated from the physical sciences in 2005, Table 8.2. The anomaly between both countries is the graduation rates in Biology. While 25,360 students graduated in biology in Ireland in 2005 only 7,720 graduated in Norway. This anomaly is partly, if not fully, explained by the fact that biology is not a matriculation subject in Norway. The progression data in the sciences in Norway shows a drop off between advanced I and advanced II in the second and third year of upper secondary education. A similar pattern is found for the theoretical course in mathematics (the X-course). It appears that students, when given the option, do not voluntarily remain in the more theoretical courses thereby denying themselves access to critical thinking skills.

Table 8.2 Total number of students graduating in the academic line of study in Norway and Ireland in 2005.

Country	Physics	Chemistry	Biology	Higher Mathematics or Advanced II
Ireland	7939	8633	25,360	9841
Norway	8601	7796	7720	7599

In this exploratory case study teacher qualification shows a rather modest academic capital in Ireland and a somewhat better picture in Norway. Up to seven teachers in Ireland and eight teachers in Norway, out of a total of twenty teachers in each country, were not qualified in the subject they were teaching. Mathematics teachers in Ireland did not have the subject as their major degree subject while in Norway only two mathematics teachers were graduates in the subject. This suggests that further large-scale research studies are required in both countries to further illuminate this important quality issue.

8.4 What types of organisational reforms were implemented?

The theoretical framework considers *organisational structures and supports* as one of the sub-themes in this exploratory study. Moving from transmission models of teaching to more transformative ways of teaching and learning, taking individual need into account, appears to suggest that different types of *organisational structures and supports* are required. For example, the physical learning environment in the classroom needs to be flexible to allow for pair-work, group work as well as individual work. In addition there needs to be formal opportunities for teachers to collaborate on a dialogue of teaching and learning and have protected time for this on an ongoing and sustained basis. This argument, made in the policy documents of both countries, is supported in the literature by Rosenholtz (1991), Hargreaves (2003) and Stoll, Fink and Earl (2003) among others.⁸⁻¹⁰ This sub-theme investigates the extent to which the reforms in science and mathematics, in

Ireland and Norway, were accompanied by organisational reforms at the level of the state and the level of the school. Rosenholtz (1991) identified four criteria for the school to promote the conception of the teacher as a professional learner.¹¹ These included formal structures for teachers to communicate with management, opportunities to collaborate, opportunities for continuing learning and the development of a culture of evaluation. Depending on the extent to which schools had these criteria in place they are categorised as *learning enriched*, *learning impoverished* or *moderately impoverished*. The sub-theme that defines this aspect of the study reads as follows:

Organisational Structures and Supports: This sub-theme regards that the new learning paradigm, recommended in the science and mathematics reforms, requires different organisational structures and supports at the level of the school – facilities, resources, teacher-teacher meetings times – than was required for previous reforms that supported more teacher-centred forms of schooling.

8.4.1 Evidence with respect to the organisational sub-theme from *policy as text* in Ireland.

A range of measures were introduced in Ireland to indicate that reforms needed some *organisational structures and supports*. State funding to upgrade laboratories, circa £3,500 per laboratory, was provided in the late nineteen nineties in addition to a Euro 10,000 grant for the purchase of datalogging equipment. The greatest possibility for structural reform came in 1998 with the introduction of middle management posts. Assistant principals and special duties teachers were appointed. However, none of the new posts was designated specifically for the support of subject-areas and it was left to the discretion of management as to how these roles were assigned. In the 2000s the Ministry introduced a national support service for teacher inservice education in the sciences, physics, chemistry and biology, at a cost of Euro 14 million approximately, for a three to four year period. A school development planning initiative assisted schools in developing policies and plans.

In 2002 it grant-aided 393 schools, to a total expenditure of Euro 630,000, at a rate of Euro 1,270 and Euro 1,905 per school. While Ireland recognized the need for an improved physical learning environment, ICT-enhanced learning and more continuing forms of inservice support it stopped short of making structural reforms at the level of the school.

8.4.2 Evidence with respect to the organisational sub-theme from *policy as text* in Norway.

Norway introduced an MST policy from 2002 onwards with an action plan for the development of the sciences and mathematics. This included building two national centres for science and mathematics education, a grant-assisted masters programme for both subject areas, a programme for the development of teacher MST and digital competence and a national policy forum, representing all stakeholders, to assist with ongoing understanding of the issue. The school development programme, costing Euro 12 million, was due to start in 2005 and be rolled out over a period of four years. After Reform-1994 the state introduced a new middle management tier and renegotiated teacher contracts. New heads of department, in science and mathematics, had much reduced teaching hours (30%) and had responsibility for convening teacher meetings and managing the budget for the subject, including purchasing of resources and paying for inservice courses. Teacher contracts not only included their class contact hours but also an additional five hours per week for preparation, planning, evaluation and additional duties involving shared responsibility with the principal and colleagues (an additional 190 hours per year). Among items evaluated in the *national pupil study* was the physical learning environment. In 2003-2004, 50,483 students in the first year of the three year cycle, indicated a satisfactory rating with their physical learning environment.

8.4.3 Evidence with respect to the organisational sub-theme from *policy as professional praxis* in Ireland.

Two of the five case study schools in Ireland had heads of department for science and mathematics – Hodgkin and Walton - and a designated annual budget. In addition Hodgkin had a part-time laboratory technician and invested over Euro 150,000 for the support of science infrastructure. All five schools availed of the national science support services. There was less emphasis on organisational needs for mathematics teachers. While reforms in 1992/1994 made the final mathematics examination more student-friendly the state remained largely silent on organizational reforms. However, one case study school had recently appointed a head of department for mathematics – Walton - and was about to purchase software for teaching the subject. Science and mathematics teacher meetings in these case study schools were all informal and outside the time-table.

8.4.4 Evidence with respect to the organisational sub-theme from *policy as professional praxis* in Norway.

In Norway a different picture emerges in respect of this sub-theme. Three of the five case study schools – Abel, Franklin and Curie - redesigned their science laboratories, opting for circular seating arrangements, costing from Euro 40,000 to Euro 200,000, to promote better team work. HODs convened teacher meetings and managed budgets ranging from Euro 7,000 to Euro 15,000 per annum. Subject-specific teachers meetings – in addition to general staff meetings - were held inside the school-day and a number of different permutations were found including weekly meetings, two meetings per month or ten meetings per year.

8.4.5 Concluding perspectives with respect to the organisational sub-theme from Ireland and Norway.

In conclusion, with respect to organisational structures and supports, a number of cross-national similarities and differences emerged (Table 8.3). It is clear from the evidence that Norway was much further along the road less traveled in respect of these reforms. In Norway school-based reforms mirrored national mandates while in Ireland the arrangements were more ad-hoc, variable and informal. However, while the level of investment in Norway exceeded that of Ireland, by 2003-2004 it had not yielded any significant increase in student uptake in the physical sciences or mathematics (see section 8.3). However, evidence from the macro- and micro-levels of this study, show that policy documents and case study schools recognised, in a variety of ways, that new student-centred learning approaches required different *organisational and structural supports*. What remains unclear is the way this sub-theme fits into the overall complex mosaic of factors that encompass the development of school-based learners at the level of science and mathematics education.

Based on Kohn's (1989) conception of making inferences from cross-national differences it was decided to view the differences emerging in this sub-theme with caution.¹² Further cross-national research could further illuminate this sub-theme, and would involve revisiting this research question in both countries to further explore the possible relation between organisational efforts and uptake in the physical sciences and mathematics. The finding emerging from this sub-theme of the study may be stated as follows: *Organisational structures and supports* appeared necessary, but not sufficient to empower schools to implement the new pedagogical reforms for learning in upper secondary science and mathematics academic education. The recommendation emerging from this aspect of the study suggests that systemic structural reforms are required in schools in Ireland if

subject-based and school-based teacher-teacher collaboration are to become the norm (Recommendation 8.10.1).

Table 8.3 The *organisational supports and structures* for teaching science and mathematics in Ireland and Norway 2003-2004.

Structures	Ireland	Norway
Infrastructure	The schools had between one and five science laboratories. All schools had one computer room, with one school having two computer rooms. With the exception of one school with state-of-the-art facilities, all schools had moderate standards in the science laboratories	The schools had between three to four science laboratories and three to five computer rooms. Three of the five schools in this study had above average facilities with two schools having state-of-the-art facilities.
Budgets	Two schools had a science budget of approximately Euro 2,500 per annum. Most mathematics teachers, with one exception, saw little need for a mathematics budget. <i>If you need something, you come to the table and you look for that...I've never refused a member of staff anything they wanted in their classroom ...but I don't allocate them €5,000 and say you have to spend that this year...because the budget we get is for the school, and the way I look at it is, what's in the best interests of the school. (management)</i>	The Head of Department had responsibility for managing the science and mathematics budget. The size of this budget varied from between Euro 7,000 and Euro 15,000 per annum. <i>we are fairly well off as for getting what we need for teaching...part of the budget is split into three, for science, for the social science department and for languages..... we have about 80,000 or 90,000 Kroner...we can travel if we want to for about 60,000, or we can buy equipment. (management)</i>
Time-Tabled Meetings	All meetings of science and mathematics teachers were held outside the school time-table.	Each Head of Department was given responsibility to convene meetings and these took place within the time-table.

8.5 How has pedagogy and assessment changed as a policy reform?

In the beginning of this century it was recognized that students needed to emerge from upper secondary school knowing as much about how they learned as much as knowing

what they learned. The new knowledge society required self-directed learners capable of higher order thinking. Theories of learning had evolved, over the forty five year timeframe of this study, from behaviourism to cognitivism to constructivism to connectivism to more eclectic models in the early years of this century. Learning, according to Stoll, Fink and Earl (2003), was perceived to be social, emotional, intellectual, non-linear and erratic.¹³

Teachers were required to take account of the individual learning needs of students. A large scale synthesis of literature in New Zealand in 2003 developed a framework for pedagogical practice that included planning and reflection for teachers and using a variety of teaching approaches to suit individual learning needs.¹⁴ This thinking was supported by the recognition of the need for a continuous feedback loop which was the basis of Black and Williams's (1998) argument with regard to assessment for learning.¹⁵

At that time the essentialist knowledge conception of science and mathematics teachers was being challenged and new researchers in the field, Driver and Bell (1986), Boaler (1997), Atkin and Black (2003) and Bell (2005), recommended transformative, in preference to transmission, models of teaching for learning.¹⁶⁻¹⁹ A pedagogical paradigm shift had taken place and, according to Lingard et al (2001), there was a pressing need to put pedagogy at the heart of educational policy reform.²⁰ Pedagogy was being reconceptualised as a discourse of learning. The sub-theme that defines this aspect of the study reads as follows:

Pedagogy and Assessment: This sub-theme considers the pedagogical practices recommended in the reforms in science and mathematics upper secondary academic education. This sub-theme is related to teachers' everyday work and inextricably links teaching, learning and assessment for the development of a culture of learning.

8.5.1 Evidence with respect to the pedagogical sub-theme from *policy as text* in Ireland.

Evidence from policy documents, from 1960-2000, showed that Ireland remained largely silent on pedagogical practices in science and mathematics. The exception was the occasional mention of the need for science subjects, from the 1980s onwards, to be taught as experimental subjects. This changed with the science reforms in the early 2000s. Now the syllabuses and new NCCA teacher guidelines all recommended using a variety of teaching approaches and gave a list of mandatory student experiments. Self-directed learning and critical thinking were promoted. However there appeared to be some lack of clarity between these official documents in science education and the thrust of the examination papers. The assessment system did not change from an externally marked final written examination. Evidence from the policy documents show that Ireland, at the time of the case study research, was recommending teaching using a variety of approaches, to promote an inquiry stance in science, self-directed learning and critical thinking. Policy documents with respect to upper secondary, higher and ordinary level mathematics, continued to remain largely silent on pedagogical reforms.

8.5.2 Evidence with respect to the pedagogical sub-theme from *policy as text* in Norway.

Evidence from the policy documents in Norway showed that previous reform waves in 1974 had focused on curricular and structural changes. Reform-1994 focused primarily on pedagogical and quality reforms. Science subjects were reformed in 1997 and mathematics in 2000. The science subjects were all modernized in content. Physics had the least and biology the most changes. They were all made more relevant to real world applications.

Mathematics reforms reduced subject matter content and required a more constructivist and eclectic approach to teaching and learning.

These curricular reforms were all overshadowed by the pedagogical reforms. Teachers were required, by statutory obligation, Section 3-2-1 of the Education Act 1998, to use *adapted teaching*, a form of differentiated teaching, to suit the learning requirements of each individual student. The teacher was to act as guide and planning partner with students. Students were to have increased freedom to choose and take more responsibility for their own learning. Assessment involved a school-state partnership system, with teachers assessing their own students and a percentage of students being assessed through state examinations in order to maintain national standards.

8.5.3 Evidence with respect to the pedagogical sub-theme from *policy as professional praxis* in Ireland.

Evidence from the exploratory case study research in Ireland in 2003-2004 shows that management and teachers were struggling with the new paradigm shift to teaching for learning. Management in Boole, Hamilton, Parson and Walton all mentioned the academic focus of their school. The replication trend found in this multiple case study was the level of contestation of the reforms by the majority of management and teachers (Table 6.6 in Chapter Six). This included twenty two respondents, from a total of thirty voices in the study. Four respondents were deeply sceptical of the reforms, a chemistry teacher in Hamilton, a biology teacher in Parsons, a mathematics teacher in Parsons and a mathematics teacher in Hodgkin. They based their justification on the assessment system. However one science teacher in four different schools had managed to change – a chemistry teacher in Boole, a chemistry teacher in Parsons, a physics teacher in Walton and a biology teacher in Hogkin. Two other teachers – a biology teacher in Boole and a

biology teacher in Hamilton - appeared to be close to the tipping point. In Hodgkin dissonance was found between management and teachers. The principal, noting her leadership role, questioned existing school structures and forms of inservice education.

8.5.4 Evidence with respect to the pedagogical sub-theme from *policy as professional praxis* in Norway.

Evidence from the case study schools in Norway show that management and teachers were also struggling with the new paradigm of leading a culture of learning. Management stressed the academic success of their schools – Abel, Bohr, Franklin and Watson - while the principal in Franklin described their school as traditional. The principal in Watson noted that pedagogical reforms had not fully made it into the life of the school even though they had been involved in the early pilot phase of this reform for over ten years. The head of department in Abel mentioned her pedagogical leadership role and her commitment to helping teachers use new methods of teaching and learning. She stated her difficulty in having this dialogue with teachers who largely saw their role as *covering the course*. Five teachers in these case study schools - one chemistry teacher in Abel, one biology teacher in Franklin, one physics teacher in Watson, one biology teacher and one mathematics teacher in Curie – were adapting the reforms. However, the level of contestation of the reforms, twenty one out of thirty voices, was high and indicated the level of challenge generated by the reforms.

8.5.5 Concluding perspectives with respect to the pedagogical sub-theme from Ireland and Norway.

Evidence from analysis of policy documents and the exploratory case study research findings, in both Ireland and Norway, show dissonance between the rhetoric and reality of reform, from the perspective of management and teachers. The chain of evidence in the

case study research shows that the level of contestation of the reforms – twenty two voices in Ireland and twenty one voices in Norway - was similarly high in both countries. It shows that management and teachers, while willing to engage with reforms, are struggling between two worlds, the pre-reform world and the post-reform world. The majority of management and teachers in the case study schools were of a traditional mind-set and aware of their obligation to support students gain access to third level education. However a smaller and significant number of teachers in this study, four teachers in Ireland and five teachers in Norway, were adapting the reforms. These findings suggest that some type of contestation is necessary if management and teachers are to adapt and make their own of the reforms. From the collective evidence it is possible to conclude that, in the early years of policy implementation, using Snyder, Bolin and Zumwalt's (1992) mutual adaptation model of reform, there is *a phase of contestation* by management and teachers.²¹ This *phase of contestation*, where management and teachers are struggling between two worlds, needs to be perceived by policymakers as a prelude to ownership of the reforms rather than an undesirable aberration. This finding leads to the recommendation that *the phase of contestation* in policy implementation needs to be planned for, supported and included in a broad-based and sustained model of inservice education that will assist the school community move closer to reform (Recommendation 8.10.2).

8.6 What are the implications for teaching as a professional praxis?

The conception of teaching changed during the forty five year period of this research study. The journey was one of movement from a craft base to a professional base. By the end of this research, while the professional base for teaching was more assured, the nature of the knowledge-practice relationship for teachers was a contested area. Teaching as a professional praxis recognised the need for a specialist knowledge base while teaching involved high task complexity, collaborative work, pre-planning and leading learning for

individual student need and engaging in a form of systematic reflective praxis, through self-evaluation and peer evaluation. This conception of teaching was supported in the literature by Rosenholtz (1991), Cochran-Smith (1999), Sugrue (2002) and Darling-Hammond and Bransford (2005).²²⁻²⁵ The model chosen to underpin this sub-theme of the study was the *post-modern professional model* of Hargreaves and Goodson (1996).²⁶ Research in the early years of this century identified that professional learning environments and situated learning were best supported through communities of practice, action learning and broader more horizontal models of support as argued, among others by Engeström et al (1995) and Wenger (1998).^{27,28} The sub-theme that defines this aspect of the study reads as follows:

Teaching as a Professional Praxis: This sub-theme regards the teacher as a professional learner, within a post-modern conception of the teacher as professional, and recognizes the need for teacher collaboration, pre-preparation for teaching for individual need, teacher evaluation, both self-evaluation and peer evaluation, and opportunities for teacher continuing learning and education.

8.6.1 Evidence with respect to the teaching sub-theme from *policy as text* in Ireland.

Evidence from the policy documents showed that by the early years of this century Ireland had established a *Teaching Council* focused on progressing the teacher as a professional. Quality reforms to support this conception included *Whole School Evaluation* and a *School Development Planning Initiative*. While it was recommended that teachers collaborate and teach reflectively, and while there were many national reports in relation to the multiplicity of roles for teachers, there was no national policy plan for teacher education into the future. A significant state investment was made in inservice support for science teachers, 2000-2004, with a prime focus on experimental and experiential methods. Evidence from the *SDPI Annual Report 2002* showed that schools themselves

did not place teaching and learning and reflective practice high on their agendas and, in many cases, their development days were focused more on fulfilling legal obligations.

8.6.2 Evidence with respect to the teaching sub-theme from *policy as text* in Norway.

Evidence from the policy documents in Norway show that the conception of the teacher as professional was supported by the introduction of a new middle management tier in the mid nineteen nineties and new work-hour agreements with teachers in the early years of this century. This resulted in formal structures inside schools, Heads of Department with reduced teaching hours, management-teacher interchange and teacher-teacher meetings. Teachers were required, by statutory obligation, to engage in *adapted teaching*, to lead learning through differentiated teaching for individual student need and collaborate during their working week with colleagues. New agreements for teachers, agreed with the teacher unions, gave more flexible work arrangements at school. Teachers were engaged in shared responsibility for planning, collaborating, assessment and evaluating their curricula with management and colleagues. This was stipulated at 5-hours per week, or 190 hours per year, in addition to classroom teaching. Voluntary inservice education was provided through the county education directorate and there was a range of courses to choose from. Schools were obliged to send annual reports to the county education authority.

8.6.3 Evidence with respect to the teaching sub-theme from *policy as professional praxis* in Ireland.

Evidence from the case study schools in Ireland show that structures for teacher-teacher meetings varied between schools. Two schools had subject departments – Hodgkin and Walton - and a head of science and mathematics. The other three schools had informal arrangements in this regard. Science teachers indicated they used a variety of teaching approaches with an emphasis on teacher instruction, questioning and experimental work.

Four teachers had moved beyond this – a chemistry teacher in Boole and Parsons, a physics teacher in Walton and a biology teacher in Hodgkin - and were developing more learning-centred approaches. Mathematics teachers displayed an essentialist epistemology, using teacher instruction and questioning as their main teaching approach, and focused on covering the course in a limited time-frame (see Table 6.4 in Chapter Six). All teachers in this study stated that they had not been involved in a formal evaluation of their science or mathematics programme.

8.6.4 Evidence with respect to the teaching sub-theme from *policy as professional praxis* in Norway.

Evidence from the case study schools in Norway showed that systemic structural reforms ensured that teacher-teacher and management-teacher meetings were formalised. Science teachers adopted a number of teaching approaches, using teacher instruction, questioning and experimental work most frequently. Mathematics teachers were far less adventurous, opting for teacher instruction and questioning as their main teaching strategy (see Table 7.13 in Chapter Seven). Four of the five schools were conducting experiments on teaching and learning mathematics and self-directed learning and were making some progress in evaluating these. Nineteen out of twenty teachers in this study – the physics teacher in Watson was the exception - were not involved in a formal evaluation of their science or mathematics courses of study.

8.6.5 Concluding perspectives with respect to the teaching sub-theme from Ireland and Norway.

In conclusion, evidence from the theoretical frame for this sub-theme, together with the policy documents and case study schools in Ireland and Norway, show that changing to a learning paradigm involved a deep cultural change for schools, which was underestimated

by policymakers as regards its complexity and resulting tensions. While the policy documents in both countries espoused teaching as a professional praxis the reality at the level of the ten case study schools presented a rather different picture. There were opportunities, in both countries, for teachers to attend inservice days related to the reforms. Teachers self-reported using a variety of teaching methods with teacher instruction their most frequent mode, especially for mathematics teachers. There were opportunities for collaboration, formal modes in Norway and more informal in Ireland. According to the management of Boole, Parson and Hodgkin in Ireland and Bohr and Franklin in Norway developing a culture of evaluation would require new supports. All science and mathematics teachers in the case study schools in Ireland and nineteen out of twenty teachers in the case study schools in Norway – the physics teacher in Walton was the exception - indicated that they had not taken part in a formal evaluation of their science or mathematics programmes.

From the qualitative evidence in the case study schools it appears that Hargreaves and Goodson's (1996) model of *post-modern professional* was too advanced for this study.²⁹ Their *flexible model* of teacher professionalism would be more appropriate.³⁰ This model is based on a shared sense of professional community and cultures of collaboration or, in some instances, contrived collaboration. However, these shared cultures maybe rather weak as they are often ring-fenced, practitioners sharing with fellow practitioners, and deprived of the intellectual challenge, subject knowledge, pedagogical knowledge and professional learning knowledge that comes from engagement with specialist scholars, a range of other actors and research findings. It is clear from the findings that management and teachers need new tools, dispositions and knowledge if they are to successfully engage in evidence-based evaluation practices (Recommendation 8.10.3).

8.7 What are the implications arising from this study for the policy process?

The cross-national comparative nature of this mixed methods research study presented the opportunity for a broader perspective of the policy process than might have been achieved in one country only. The policy process was conceptualized in a novel way as a complex social phenomenon, along the lines argued by Crossley and Watson (2003).³¹ Adaptations of Bowe, Ball and Gold's (1992) and Buachalla's (1988) models of the policy process considered science and mathematics policy at two levels, *policy as text* and *policy as professional praxis* across two dimensions: *process* and *organizational* dimensions.³²⁻³³ Policy did not simply diffuse into the school community without engaging the minds of management and teachers, regarded by Broadhead (2002) as *second phase policy makers*.³⁴ Using the knowledge society as a backdrop science and mathematics teachers were viewed, as argued by Giroux (1988), as public intellectuals and professional learners rather than mere functionaries of the state.³⁵

8.7.1 Evidence from *Policy as Text*, Ireland.

Official policy documents in Ireland over the forty five year study show that they emanate from a consultative process which is largely dialogical and political in design. The policy process is a top-down political process operating at the level of the state and the school. Various Ministers of Education made their mark on senior cycle education over the years. Minister Michael Woods, T.D. introduced during his time a range of science reforms. The DES perceived itself as a policy formulator and the school as the site of policy implementation. While Ireland investigated the problem of declining interest in the physical sciences and mathematics, and published the *Task Force Report on the Physical Sciences* 2002, it stopped short of formulating a long term policy in this regard.

8.7.2 Evidence from *Policy as Text*, Norway.

Official policy documents also show that Norway operated a consultative, dialogical and political education policy process. It's education system functioned at three levels: state, school and county authority. It operated a top-down system. Minister Clemet was responsible in 2002 for starting a national MST policy process. The MER perceived itself as policy formulator, together with the country education directorate, with the school perceived as the site of policy implementation.

8.7.3 Evidence from *Policy as Professional Praxis*, Ireland.

A *mutual adaptation process* was taking place within the case study schools in Ireland. Overall the busyness and exertion of management and teachers was evident together with a preoccupation with the state examination system. While there were a number of different perspectives offered in the study, it shows that a small number of teachers engaged with the reforms. However, a majority of management and teachers were contesting the reforms – twenty two respondents from a total of thirty voices. This chain of evidence showed a traditional mind-set among management and teachers and a big gap between the rhetoric of the reforms and the reality of the perspectives of management and teachers. The tension identified arose from the perceived dichotomy between the moral obligation to assist students achieve access to higher education and take time-out to show them how to learn.

8.7.4 Evidence from *Policy as Professional Praxis*, Norway.

A *mutual adaptation process* was also taking place within the case study schools in Norway. Management and teachers in these case study schools were conscious of the nature of the pedagogical reforms and the expectation for *adapted teaching* to suit individual need. While five teachers were engaging with the reforms - one chemistry teacher in Abel, one biology teacher in Franklin, one physics teacher in Watson, one

biology and one mathematics teacher in Curie - the majority of management and teachers showed a traditional mind-set and were struggling with assisting students achieve access to higher education. While four out of five schools were engaged in experiments to promote learning uncoupling teacher-student dependency was proving a challenge.

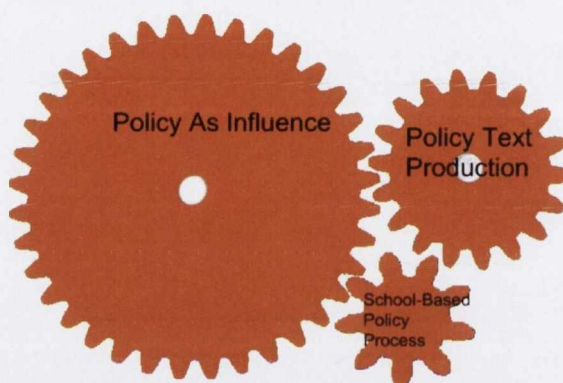
8.7.5 Concluding Cross-National Perspectives on the Policy Process.

When the macro- and micro- similarities and differences are studied in detail, for each country, together with the conceptual basis of this aspect of the study, it is clear that the top-down rational linear conception of the Ministry as the site of policy formulation and the school as the site of policy implementation is far too simplistic (Table 8.4 and Table 8.5). There is evidence in this study of dissonance between the rhetoric and reality of the policy process – twenty two voices in Ireland and twenty one voices in Norway from a total of thirty voices in each country - as perceived at the level of management and teachers. The reforms, largely related to a pedagogical paradigm shift related to teaching for learning, have not been absorbed fully into the overall life of the schools. This gap between the rhetoric and reality of the reform policy suggests that the policy process, as a top-down model, needs to be reconceptualised.

The model of the policy process, presented by Bowe, Ball and Gold (1992) is reconceptualised in this study, from the evidence gleaned with regard to the dissonance between rhetoric and reality, to a more organic, dynamic model.³⁶ The model proposed consists of three interlocking cog-wheels, of varying size and significance, with the underlying theme of motion - when one turns all turn (Figure 8.2). This model represents the organic socio-political dynamic interactive nature of the policy process. One cog-wheel represents the ministry of education which produces the *official policy text*, the rhetoric of the curriculum reform. This wheel generally, in a democratic society, turns

only after a period of critical debate on the need for change. This is represented by the cog-wheel representing the public policy sphere and includes the *policy as influence* of the key stakeholders. When both of these turn the school responds with its own insights and a feedback loop is set in motion. In this way the school-based policy process is a recognized part of a coherent policy cycle. In this model management and teachers are viewed as key actors in this policymaking process.

Figure 8.2 The dynamic socio-political interactive nature of the policy process.



Source: Author.

This organic model of the policy process suggests that when official policy documents are presented to the school they are offered more as national guidelines and discussion documents rather than as policy directives or mandates (Recommendation 8.10.4). This newer conception of the policy process signals the need for newer models of inservice education. Instead of the more traditional vertical top-down models of inservice education broader-based and more horizontal models appear to be required. In this new model teachers not only share experiences with other teachers but are expected to engage in a dialogical process with a range of other actors, such as students, management, parents, researchers, policymakers and specialist scholars. In this way the policy process connects

management and teachers into a coherent national grid of political, professional and intellectual support more appropriate, for the continuing education and professional learning of the teaching force, in a knowledge society (Recommendation 8.10.5)

Table 8.4 Some similarities and differences in upper secondary *policy as text* reforms in Ireland and Norway 1960-2005.

Aspect	Ireland	Norway
Upper secondary education	2-year or 3-year experience depending on access to transition year programme.	Statutory right to three year cycle. Education Act, 1998 Section 3-1.
Curricular Reforms (Science)	180-hour programmes over 2-years culminating in a final written state examination. Two levels of specialisation: Higher and Ordinary. List of Mandatory Student Experiments.	Courses of study for one year duration. General courses of study (2FY, 2KJ, 2BI) and more specialised courses (3FY, 3KJ and 3BI). Physics all 184-hour courses while chemistry and biology vary between 112-hour and 184-hour courses (advanced I or advanced II).
Curricular Reforms (Mathematics)	180-hour courses of study over a 2-year period. Three levels of specialisation: Higher, Ordinary and Foundation. Assessed by state written examination(s).	Two levels of specialisation, theoretical (X-course) and applied (Y or Z) courses. Education Act 1998 Section 3-4.
Pedagogical Reforms	Variety of teaching approaches recommended to suit individual need (syllabus requirement, teacher guideline requirements and WSE requirements).	Adapted Teaching. Education Act, 1998 Section 1-2. Teaching adapted to suit the individual need of students. Student and teacher as planning partners.
Assessment Reforms	Terminal written state examinations in science and mathematics.	School-based assessment and state examinations (oral, written and practical). Results combined for matriculation. School-based marking conferences.
Teacher Inservice Education	Available in the early stage of implementation of a new reform through a National Support Service. Paid for directly by state. Voluntary. School principal with responsibility for promoting teacher professional development: Section V, Part 23 (20 (c) Education Act 1998.	Subject-specific and generic inservice courses available through the county education directorate. Paid for from the HOD budget. Voluntary. Grant-assisted Masters programmes for science and mathematics teachers.

Table 8.5 Some management-teacher perspectives of the policy process.

Reform	Management-Teacher Perspective in Ireland	Management-Teacher Perspective in Norway
Context	I don't know a huge amount about it in detail but I believe (there is) mandatory experiments as I understand it, and (they're) only going to be spot checked. (<i>management</i>)	it is in the subjects, they have changed (somewhat) and the way of teaching should be changing but I think that hasn't been taken serious enough, that is the main criticism through the reform, it hasn't got into the life of the school enough. (<i>management</i>)
Pedagogical Reforms	Most of our students would be ambitious towards third level and getting into the university system. In fact most of them will get into it, whether it is in this country or (somewhere) else. (<i>management</i>) I don't really use the blackboard much at all, a lot of the overhead projector, I have acetates made out, because they're colourful and you can have diagrams and it attracts their attention and it saves a lot of time as well. (<i>science teacher</i>)	I would say first of all the school is pre-university...most of our students go through university afterward. (<i>management</i>) A lot of these alternative math teaching strategies that we have seen in Norway take a lot of time, you know, you build the model or you go out and look at architecture and the geometry of architecture something you could do in thirty minutes in the classroom is taking you two and a half hours in the field and they feel that they don't have enough time (to teach like this). (<i>mathematics teacher</i>)
Assessment Reforms	If the weight is so much on practical work now you cannot reflect that on a written paper, it doesn't make sense to be writing about your experiment on a written paper. (<i>management</i>)	when it's something like marking, I take that (seriously) because I feel it's important and it has to be done correctly. (<i>management</i>)
Evaluation Reforms	it's still in the early embryonic stages in senior cycle. I think a lot depends on the culture we have grown up in ourselves and often teachers and people in the teaching system are products of the culture and they act out the culture they grew up in and it takes enlightenment of new ideas and new methods and exemplar methods (to do things differently). (<i>management</i>)	the students inspect us.....They answer over thirty questions about learning....We have got the reports for our school how the students do...and the results are published on the internet...and the exam results will all be published in the same website...when it is finished we can go into the website and we can compare the evaluation research from the exams and the research from the local directorate. (<i>management</i>)

8.8 What are the implications for uptake in the physical sciences and mathematics?

With regard to the decline in uptake of the physical sciences and mathematics in upper secondary education in Ireland this study identifies some policy lacunae, some areas for further research and offers some blueskies recommendations. National statistics across the forty five years of the study shows that at no point between 1960 and 2005 did more than one-in-five students choose the physical sciences or higher level mathematics. Data from Norway indicate that when students are facilitated to choose they gradually move away from more theoretically demanding courses. One value of a cross-national comparative study, argued by Kohn (1988), is that it can assist seeing beyond national policy agreements.³⁷ This research study shows that policy directives in Ireland, such as increasing hands-on experimental work, using datalogging in science and the prospect of a second assessment component, have all been tried and tested in Norway and, by themselves, have not succeeded in improving uptake in the physical sciences or mathematics.

The quality issue of teacher qualification may also hold some element of a solution to this complex issue. In this exploratory study, approximately one third of teachers in each of the multiple case studies, were not qualified to teach their subject specialism. Further large-scale research in this area is recommended. This research study also shows that while a small number of science teachers had embraced change – four science teachers in Ireland and four science teachers in Norway - others were close to the tipping point in moving from older teacher-centred to newer learner-centred perspectives. Inservice models needed to intellectually challenge teachers' essentialist epistemologies of science and mathematics teaching. Ireland needed to develop a more long term policy for school science education.

8.9 Future Cross-National Comparative Research Studies

This cross-national comparative research study raises a number of critical questions that point to the need for additional cross-national research findings. Three areas emerging from the exploratory case study research present themselves as needing further research: subject specialization, teacher qualifications and developing a culture of evaluation.

8.9.1 Specialisation in the Sciences and Mathematics.

It was intimated in the case study research findings in Ireland that teachers and management perceive ordinary level science courses as fall-back positions for students rather than courses of study in their own right. It is also intimated that foundation level mathematics in Ireland is not perceived as a worthwhile study as it does not lead to matriculation. This may also be the position with respect to choosing biology in Norway and the fall off of students taking the more theoretical courses, in the physical sciences and mathematics, over the three years of high school. Further research is needed to further illuminate this problem.

8.9.2 Teacher Qualification

Teacher qualification is another area that this study illuminates as a potential issue in science and mathematics teaching. Not all teachers, in upper secondary education, in either Ireland or Norway, were qualified in the subject they were teaching. Further large scale research is required to fully investigate this issue.

8.9.3 Developing a Culture of Evidence Based Evaluation

While Norway made provision for mathematics and science teachers to meet regularly this study did not enquire into the quality of these meetings. Further research is needed to ascertain to what extent teacher meetings in Norway focused on dialogue relating to

teaching, learning and evaluation in science and mathematics. The research needs to focus on the benefit and challenges for schools seeking to build a more open culture of evidence-based evaluation.

8.10 Major Findings, Reconceptualisations and Recommendations

The findings from this study have now been reflected on and lead to the formulation of a number of major findings or conclusions, reconceptualisations and recommendations. The three major findings from this study of the policy process, in upper secondary science and mathematics, emerge through O’Buachalla’s (1988) adapted dimensions, organizational and process dimensions, and from the small but significant quantitative study.³⁸ In addition two theoretical generalisations arise from the qualitative evidence, as predicted by Evans (2000) and Eisenhardt (2002).^{39,40} One reconceptualisation arises from the identification of a distinct phase in the process of school-based curriculum implementation, based on the model proposed by Snyder, Bolin and Zumwalt (1992). The other includes an extension of Bowe, Ball and Gold’s (1992) model of the policy process.^{41, 42} The three major findings from the study may be stated as follows:

- *Organisational structures and supports* appear necessary, but not sufficient to empower schools to implement pedagogical reforms for learning in upper secondary science and mathematics academic education.
- The chain of evidence in this exploratory case study research, in both countries, shows that there was a high level of contestation of the reforms. The majority of management and teachers in these case study schools, in both Ireland and Norway, were of a traditional mind-set and caught in a dilemma between supporting students achieve access to higher education and taking time to implement newer learner-centred pedagogical reforms. From the collective evidence it is clear that,

in the early years of policy implementation there is a *phase of contestation* by management and teachers. This *phase of contestation* where management and teachers are struggling, between both pre-reform and post-reform worlds, needs to be perceived by policymakers as a prelude to ownership of the reforms rather than an undesirable aberration.

- This research study shows that policy directives in science education in Ireland, such as increasing hands-on experimental work, using datalogging in science and the prospect of a second assessment component, have been tried and tested in Norway and have not succeeded in improving uptake in the physical sciences or mathematics.

The study gave rise to two theoretical generalisations include the following:

- The *mutual adaptation model* of curriculum reform, proposed by Snyder, Bolin and Zumwalt (1992), suggest that when reforms enter the school key actors, such as management and teachers, engage in a meaning-making process and interpret the reforms based on a number of factors, including their own personal histories.⁴³ This model can now be extended to include a distinct phase - the *phase of contestation*.
- The model of the policy-process by Bowe, Ball and Gold (1992) has been reconceptualised, based on the evidence in this study of the gap between rhetoric and reality, to a model of the policy process that is more organic and holistic, that considers all actors as policymakers, including management and teachers, and requires feedback pathways.⁴⁴ In this new model *policy as text* is regarded more as *national guidelines* and a *discussion document* rather than a set of immutable mandates and directives.

These findings and theoretical generalisations lead to the generation of five blue skies recommendations:

8.10.1 Systemic structural reforms are required in schools in Ireland if subject-based and school-based teacher-teacher collaboration are to become the norm and the teacher is to be recognized as a professional learner.

8.10.2 In the early years of policy implementation, in the mutual adaptation of a reform by management and teachers, there is *a phase of contestation*. This needs to be planned for, supported and included in a sustained model of inservice education which will assist the school community move closer to policy implementation.

8.10.3 Teaching as a professional praxis requires that teachers engage in self- and peer-evaluation. This missing evaluation link, in this exploratory study with science and mathematics teachers, suggests that management and teachers need new tools, dispositions and knowledge if they are to successfully engage in evidence-based evaluation practices.

8.10.4 Ireland needs to begin a dialogue, with stakeholders, schools and the public, that results in the formulation of a policy for science and mathematics education that is regarded as a national guideline and blueprint for progress into the future.

8.10.5 Instead of the more traditional vertical top-down models of inservice education broader-based and more horizontal models appear to be required. In these newer models teachers will not only share experiences with other teachers but they will also be expected to engage in a dialogical process with a range of other actors, such as students, management, parents, researchers, policymakers and specialist scholars. This will support models of inservice that intellectually challenge the essentialist epistemologies of science and mathematics teachers. It will also connects management and teachers into a coherent

national grid of political, professional and intellectual support more appropriate for the continuing education and professional learning of a teaching force in a knowledge society.

Finally the advantages and challenges of doing cross-national comparative exploratory research, of this nature, across two countries have been fully borne out in this thesis. The challenges are many, they include the need for cultural and contextual sensitivity and sensibility, the need for a deep historical insight into the phenomenon in both nations and the acceptance of the restraint that making inferences from similarities and differences, especially differences, is complex and fraught with difficulty. The advantages include the broader perspective the research brings to bear on the phenomenon under study, what might be learned from knowing similarities and differences between systems and the ability to reconceptualise and push forward the frontiers of knowledge. A number of areas for further research presented themselves from this cross-national comparative study: teacher qualifications, subject specialization and developing a culture of evaluation in schools. It appears that problems, such as the policy implementation process in science and mathematics academic education, are shared across nations. Therefore cross-national research has much to offer the field of research in exploring blue-skies possibilities and imaginings of a better world. As Arnove (2001) states it is indeed only by *knowing other realms of being can we begin to gain distance on one's own daily existence, what is unique and what is shared with others.*⁴⁵

Summary: End-Notes

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Appendix I: A comparative study of the process of reform implementation in the Senior Cycle and Videregående skolen of Ireland and Norway 9th October 2003.

1.0 This comparative study examines the process of implementation of education reforms and structures in the upper secondary systems in the past two decades of Norway and Ireland. The research will involve considering the education policies of both countries, how the policies impact on the schools, what changes have in fact happened in the classroom and in the school organisation in general. The aims of the research will be to identify the impact of policy on practice and to assess the quality of the policy process.

2.0 The development of Irish Education Policy and provision in the past thirty years will be summarised in qualitative and quantitative terms. The range of reform policies adopted and the efficacy of their implementation will be surveyed and their impact evaluated. In the past decade, the following changes have been introduced at Senior Level in Irish schools:

- Subjects: new syllabuses introduced in physics, chemistry, biology, english, home economics, music and business.
- Programmes: Transition Year, Leaving Certificate Applied, Leaving Certificate Vocational Programme, Post-Primary Language Initiative and IT 2000.
- Structures: SLSS, SDPI, NCCA, ATECI, and the NADP.
- Inservice Training: The rationale behind the reforms and what is expected from them is presented to the schools and the teachers by INSET, the national inservice training model. At present there are 22 support services supporting 22 reforms, for example, the physical sciences initiative, the biology support service, teaching english support service, and the second level support service.
- Legislation: The Education Act 1998, the Education Welfare Bill 1999 and an increasing number of statutes, circulars and directives bearing now on the organisation and functioning of schools.

These changes were introduced in the context of a falling school population and a positive economic and political environment enriched by various EU programmes.

3.0 This pilot study will examine the upper secondary system in ten schools, five in each country and will seek to analyse them on a comparative basis. The study will examine the system in both countries as they are operating at present under the current policies and will describe their functioning by means of the collected relevant statistical data. The schools chosen in Norway will offer a similar profile to those in Ireland; it is planned that the schools are representative of the geophysical and social variables in both countries.

4.0 We are interested in analysing the recent policy developments in relation to (i) school planning and development, (ii) the use of ict and other modern teaching methods to improve "learning", the (iii) provision for the teaching of mathematics and the physical sciences and (iv) inservice provision.

5.0 The study will focus on "reflective practice" and the type of "feedback" loop used by all concerned at central, regional and local levels. We are also interested in the school as "a self-evaluating community", in the opportunity for dialogue between the education stakeholders and in the "ownership" of the education initiatives and reforms.

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Dublin.

Appendix II: Final Personal Reflection

My interest in science and mathematics education has been personally shaped through a number of experiences as a student, a teacher, a regional development officer, a researcher, a lecturer and teacher educator. I view science and mathematics education through the eyes of a female born in the nineteen fifties into a large Catholic family, as a seventh child, in the West of Ireland. In my school, a rural coeducational voluntary secondary school, I studied chemistry and biology while physics was not offered as a senior cycle subject. I was the first girl in the school to take higher level mathematics in Leaving Certificate. Encouragement to proceed to university came from a number of mentors: my science and mathematics teacher and my Latin teacher. In this final personal reflection I intend to reveal my interest in pedagogical reform and my position with regard to the new learning paradigm with regard to upper secondary education.

I found science and mathematics in post-primary education liberating, intellectually enjoyable and stimulating. My science and mathematics teacher was a nun who was passionate about both subjects and made a great effort to explain everything in practical ways. In first year she told us stories and presented science as a living, interesting and imaginative subject. Big bottles of chemicals were brought from the fume-hood as we were told the story of each colourless liquid. Our imaginations were fired when we realized that if these toxic substances were released they could burn through our skin as well as eat their way through the wooden benches!

Through a seven year study in university I completed an honours degree in chemistry (major) and mathematics (minor), a master's degree in chemistry and a higher diploma in education. I loved chemistry, the experimental work we did in groups and the connectivity made between experimental findings and various theoretical conceptions. Later I choose the history of mathematics as part of my higher diploma in education and the lecturer

brought the subject to life, especially when he connected it the earlier contributions of the Romans and Greeks. It was only much later, as part of the archive study for this thesis, that I discovered he was one of the founding father of the IMTA in the 1960s. My master's degree involved an interesting study of the behaviour of siloxanes at high temperatures. The study involved using a shock-tube with a laser beam and an oscilloscope to take readings. It was far more sophisticated than test tube chemistry!

After university I taught in a total of four post-primary schools in Ireland for a period of fifteen years. I taught physics, biology and higher level mathematics mostly. To keep the flame of chemistry alive I wrote a number of school text-books that were published. It was really difficult at the time to find interesting resources to breathe life into these subjects. The mathematics text-books were totally dull with no contextual material.

Toward the latter end of that time I was employed part-time by the Department of Education as a teacher support person and later as a Regional Development Officer. I worked for three years part-time as a member of the Junior Cycle Chemistry Support Service and travelled to schools in Cork, Donegal and Dublin. In that time I observed the minimal conditions in laboratories, especially in schools that were quite prestigious. In 1995 I was seconded full time to the national support service for transition year and spent the following nine years with this service. I worked with up to one hundred post-primary schools in the west and mid-west of Ireland. The work supported the setting-up, planning and evaluation of a transition year curriculum that offered a holistic education. The experience connected me with principals, coordinators and teachers of all subject areas.

Working as a regional development officer with the Department of Education (DES) gave me an insight into the political world of education and a glimpse of the gatekeepers that play a significant role in shaping Ireland's education system. Knowledge of the world of policymakers increased when I joined the *Teaching and Learning for the 21st Century*

project in the National University of Ireland at Maynooth, as a Research and Development officer. I later became the Academic Coordinator of Teaching Practice and Mentoring in the University of Limerick. As teacher educator I worked as part of a team attempting to promote better school-based mentoring of initial and newly qualified teachers.

Opportunities congruent with this research study were presented when the national biology support service sought my assistance with a new model of inservice support. The research and development project attempted to develop the innovative capacity of biology teachers and to give some ownership for the reform to teachers. It resulted in up to one hundred new resources for teaching the subject. My research work, currently, and over the last few years with a number of European projects, Comenius 2.1 projects (teacher education), involves working with science teachers in case study schools to support teachers' reconceptualizing knowledge and bringing teachers and policymakers together to share in this dialogue and gain newer perspectives.

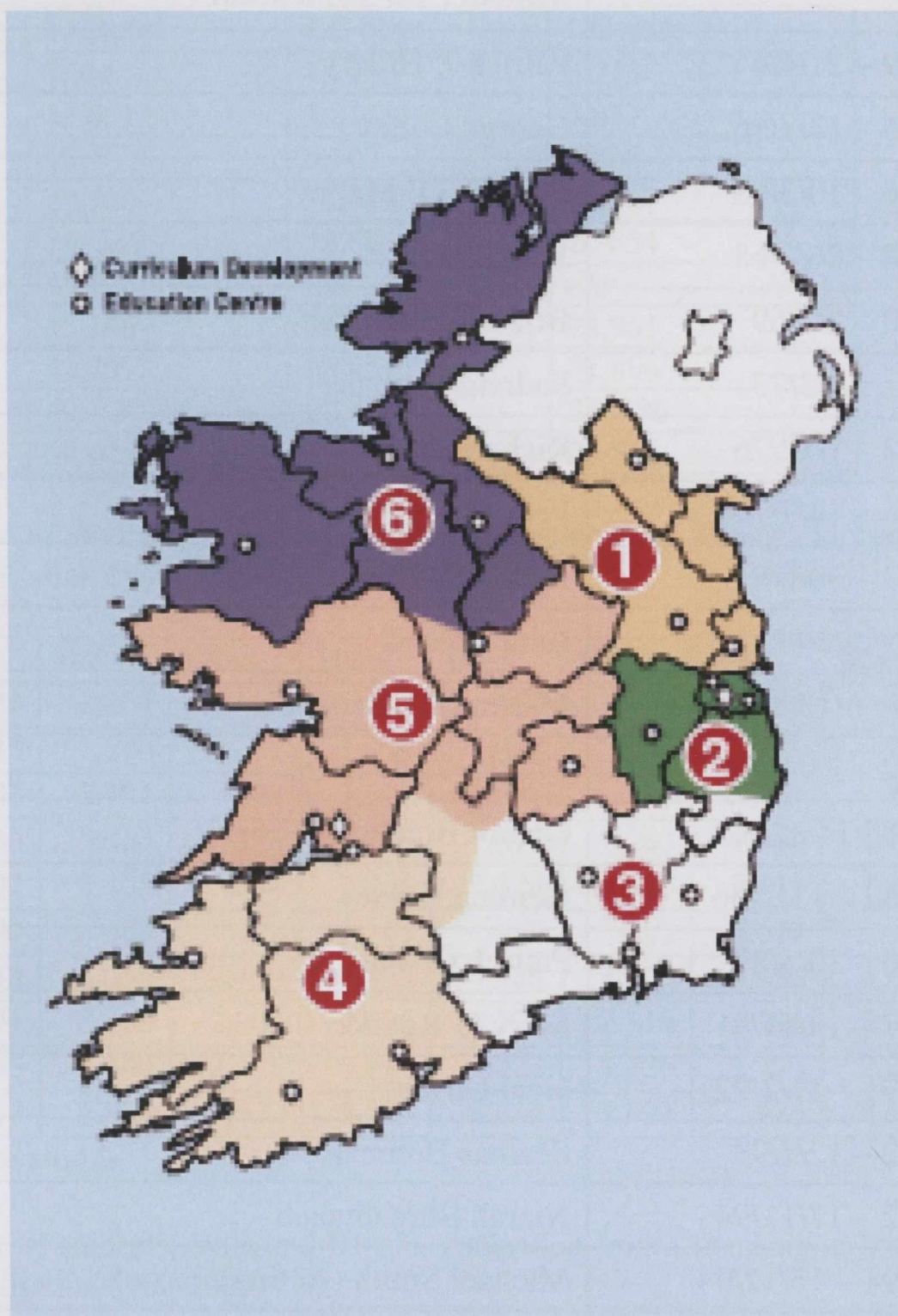
The greatest learning from me during my doctoral study was trying to make the leap from scientist to social scientist! While the scientist often attempts to draw the best straight line from the scatter graph of results the social scientist seeks to hold the complexity and ambiguity of multiple perspectives to gain a fuller and more complete picture. The other great learning for me was the value of bringing another country into the research and the way it highlighted the need to research my own country in greater depth.

With regard to the new pedagogical paradigm supporting teaching for learning my position is one of scepticism, hopefully healthy scepticism. I do not know what is the best learning approach to take. It seems that older teacher-centred approaches are not challenging enough to help young people become critical thinkers. However they might play a significant part in helping students get the basics of subjects, such as science and mathematics, so that they can progress to higher order thinking. We seem to want to get

somewhere new in teaching for learning but have few exemplars of people who have got there and willing to convince us that the journey is worthwhile.

Knowledge societies need people who can think and think laterally, creatively and critically. But does society want to make the type of investment it might take to re-educate and re-culture their teaching force? If society doesn't sufficiently value it's teaching force, and continue to intellectually challenge them and invest in their continuing education and learning, how does it hope to prepare a future generation of learners who will be open to learning, self-directed learners, able to collaborate and with a flexible and questioning spirit of inquiry. I hope that the insights, findings and recommendations from this policy research study will help to more fully understand the policy process and improve school-based reform and teacher education, in Ireland and Norway, and especially science and mathematics teacher education into the future.

Appendix III Map of Ireland showing the regional support structure of the Second Level Support Service (SLSS) in 2008.



Source: Second Level Support Service, SLSS Term 2&3 2008 Brochure, 4.

Appendix IV: Ministers for Education, Government of Ireland 1960-2005.

Year	Minister for Education
24/6/59 – 21/4/65	Patrick J. Hillery
21/4/65 – 13/7/66	George Colley
13/7/66 – 10/3/68	Donagh O' Malley
11/3/68 – 26/3/68	Jack Lynch
27/3/68 – 2/7/69	Brian J. Lenihan
2/7/69 – 14/3/73	Padraig Faulkner
14/3/73 – 1/12/76	Richard Burke
2/12/76 – 14/7/77	Peter Barry
15/7/77 – 30/6/81	John P. Wilson
1/7/81 – 9/3/82	John Boland
9/3/82 – 6/10/82	Martin O' Donoghue
6/10/82 – 27/10/82	Charles J. Haughey
27/10/82/14/12/82	Gerard Brady
14/12/82 – 13/2-86	Gemma Hussey
14/2/86 – 10/3/87	Patrick Cooney
11/3/87 – 13/11/91	Mary O'Rourke
14/11/91 – 11/2/92	Noel Davern
12/2/92 – 12/1/93	Séamas Brennan
13/1/92 – 17/11/94	Niamh Bhreathnach
17/11/94 – 15/12/94	Michael Smith (Acting)
15/12/94 – 26/6/97	Niamh Bhreathnach
26/6/97 - 27/1/00	Micheál Martin*
27/1/00 - 6/6/02	Michael Woods
6/6/02 - 17/9/04	Noel Dempsey
17/9/04 – beyond 2005	Mary Hanafin

* The name of the Department of Education was changed to Department of Education and Science with effect from 30 September 1997.

Appendix V: The number of students graduating from science in Ireland, 1960-2005.

(a) Number of students graduating in Leaving Certificate examination 1960-2005.

Year ending	LC total	LC boys	LC girls
1960	7,966	4,193	3,773
1965	11,651	5,814	5,837
1970	18,975	9,107	9,868
1975	29,206	13,519	15,687
1980	36,539	15,885	20,654
1984*	45,773	n/a	n/a
1990	55,146	26,185	28,961
1995	62,737	28,851	31,886
2000	60,737	28,851	31,886
2005	54,073	25,543	28,530

(b) The number of students, male and female, graduating from Physics at higher and ordinary levels of specialisation 1960-2005.

Year	Total	Boys	Girls	Hons	Boys	Girls	Pass	Boys	Girls
1960	1,021	1,004	17	566	563	3	455	441	14
1965	1,835	1,770	65	1,059	1,028	31	776	742	34
1970	2,607	2,404	203	1,626	1,509	117	981	895	86
1975	3,436	3,063	373	1,956	1,693	263	1,480	1,370	110
1980	5,102	4,408	694	2,968	2,478	490	2,134	1,930	204
1984*	8,790	n/a	n/a	5,161	n/a	n/a	3,629	n/a	n/a
1990	10,515	8,055	2,460	6,895	4,986	1,909	3,620	3,069	551
1995	11,091	8,283	2,808	7,695	5,376	2,319	3,396	2,907	489
2000	8,588	6,480	2,108	5,849	4,123	1,726	2,723	2,357	382
2005	7,939	5,919	2,020	5,503	3,812	1,691	2,436	2,107	329

*n/a data not-available

(c) The number of students, male and female, graduating from Chemistry at higher and ordinary levels of specialisation 1960-2005.

Year	Total	Boys	Girls	Hons	Boys	Girls	Pass	Boys	Girls
1960	1,178	1,071	107	664	624	60	494	447	47
1965	1,788	1,625	163	1,043	960	83	745	665	80
1970	3,613	2,887	726	2,679	2,113	566	934	774	160
1975	5,155	3,890	1,265	3,184	2,251	933	1,971	1,639	332
1980	6,984	4,524	2,460	4,850	2,982	1,868	2,134	1,542	592
1984*	9,084	n/a	n/a	6,389	n/a	n/a	2,695	n/a	n/a
1990	8,706	4,900	3,806	6,473	3,462	3,011	2,233	1,438	795
1995	8,462	4,412	4,050	6,738	3,351	3,387	1,724	1,061	663
2000	6,711	3,165	3,546	5,531	2,464	3,067	1,180	701	479
2005	8,633	4,500	4,133	6,032	3,812	3,488	1,333	688	645

*n/a data not-available

(d) The number of students, male and female, graduating from Biology at higher and ordinary levels of specialisation 1971-2005.

Year	Total	Boys	Girls	Hons	Boys	Girls	Pass	Boys	Girls
1971	3,757	1,212	2,545	2,188	642	1,546	1,569	570	999
1975	9,944	4,230	5,714	5,395	2,171	3,224	4,549	2,059	2,490
1980	19,309	6,410	12,899	9,692	3,408	6,284	9,617	3,002	6,615
1984*	23,307	n/a	n/a	12,382	n/a	n/a	10,925	n/a	n/a
1990	27,080	9,138	17,942	15,412	4,897	10,515	11,668	4,241	7,427
1995	31,559	10,842	20,717	19,349	5,967	13,382	12,210	4,875	7,335
2000	26,660	8,884	17,776	16,194	4,933	11,261	10,466	3,951	6,515
2005	25,360	8,082	17,278	17,482	5,113	12,369	7,878	2,969	4,909

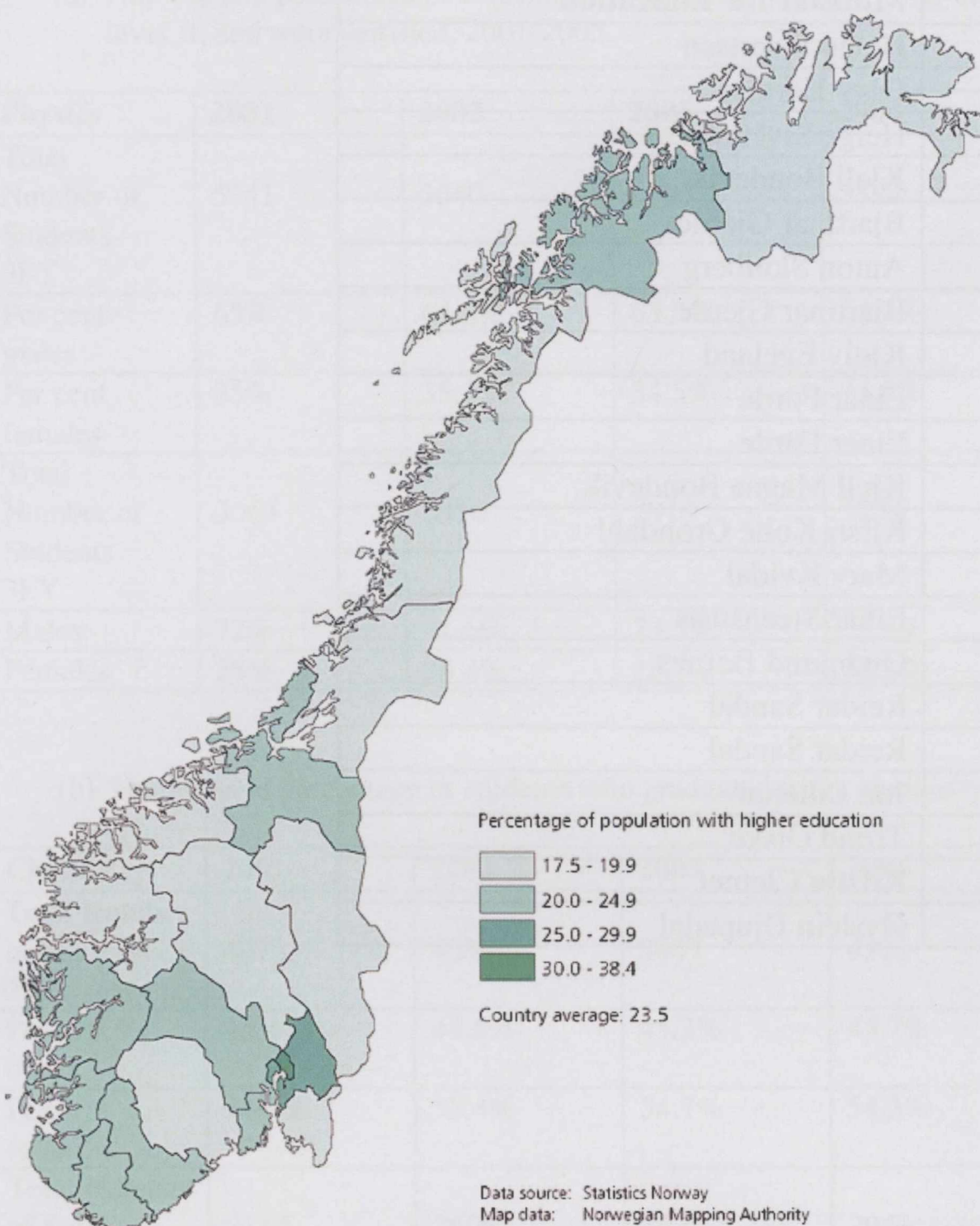
*n/a data not-available

Appendix VI: Leaving Certificate graduation numbers in mathematics, at higher and ordinary levels, 1960-2005.

Year Ending	Maths. Total	Boys	Girls	Hons. Total	Boys	Girls	Pass Total	Boys	Girls
1960	7,076	4,117	2,959	1,155	1,115	40	5,921	3,002	2,919
1965	9,642	5,646	3,996	1,930	1,802	128	7,712	3,844	3,868
1970	15,521	8,700	6,821	2,128	1,857	271	13,393	6,843	6,550
1975	26,349	13,084	13,265	2,933	2,375	558	23,416	10,709	12,707
1980	34,830	15,603	19,227	3,308	2,461	847	31,522	13,142	18,380
1984*	43,392	n/a	n/a	5,578	n/a	n/a	37,814	n/a	n/a
1990	52,972	25,213	27,759	6,767	4,348	2,419	46,205	20,865	25,340
1995	54,795	26,546	28,249	10,036	5,775	4,261	44,759	20,771	23,988
2000	58,705	n/a	n/a	10,645	n/a	n/a	42,214	n/a	n/a
2005	46,613	22,044	24,569	9,841	5,028	4,813	36,772	17,016	19,756

*n/a data not available.

Appendix VII: Map of Norway.



Source: Statistical Yearbook of Norway, 2005.

Appendix VIII: Ministers for Education in Norway 1960-2005.

Year	Minister for Education
1960-1963	Helge Sivertsen
1963	Olav Kortner
1963-1965	Helge Sivertsen
1965-1971	Kjell Bondevik
1971-1972	Bjartmar Gjerde
1972 – 1973	Anton Skulberg
1973-1976	Bjartmar Gjerde
1976-1979	Kjølv Egeland
1979-1981	Einar Førde
1981-1983	Einar Førde
1983-1986	Kjell Magne Bondevik
1986-1988	Kirsti Kolle Grøndahl
1988-1989	Mary Kvidal
1989-1990	Einar Steensnæs
1990-1995	Gudmund Hernes
1995-1996	Reidar Sandal
1996-1997	Reidar Sandal
1997-2000	Jon Lilletun
2000-2001	Trond Giske
2001-2005	Kristin Clemet
2005-	Øystein Djupedal

Appendix IX: Number and percentage of students who passed science in Norway.

(a) Number and percentage of students who passed physics, at advanced level I and advanced level II, and were certified, 2001-2005.

Physics	2001	2002	2003	2004	2005
Total Number of Students 2FY	5341	5640	5306	5524	5590
Per cent males	65%	64.8%	65.5%	64.2%	62.7%
Per cent females	35%	35.2%	34.5%	35.8%	37.3%
Total Number of Students 3FY	3064	3016	2918	3074	3011
Males	72%	71.6%	73.3%	71.5%	71.4%
Females	28%	28.4%	26.7%	28.5%	28.6%

(b) Number and percentage of students who graduated from chemistry, 2001-2005.

Chemistry	2001	2002	2003	2004	2005
Total Number of Students 2KJ	4075	4059	3947	4371	4669
Per cent males	45.4%	44.6%	45.3%	45.7%	46.3%
Per cent females	54.6%	55.4%	54.7%	54.3%	53.7%
Total Number of Students 3KJ	2714	2606	2637	2943	3227
Per cent males	48.5%	45.1%	47.1%	48.4%	49.5%
Per cent females	51.5%	54.9%	52.9%	51.6%	50.5%

(c) Number and percentage of students who graduated from biology, 2001-2005.

Biology	2001	2002	2003	2004	2005
Total Number of Students 2BI	3985	4150	3799	4118	4494
Per cent males	23.8%	25.1%	26%	28.7%	28.5%
Per cent females	76.2%	74.9%	74%	71.3%	71.5%
Total Number of Students 3BI	2753	290	2623	2817	3226
Per cent males	21.9%	23%	24.7%	26%	26.9%
Per cent females	78.1%	77%	75.3%	74%	73.1%

(d) Number and percentage of students who passed natural science, in the foundation course, and were certified, 2001-2005.

Natural Science	2001	2002	2003	2004	2005
Total Number of Students	19 297	20 057	19 749	19 921	20 117
Per cent males	43.5%	44.8%	44.3%	45.1%	44.1%
Per cent females	56.5%	55.2%	55.7%	54.9%	55.9%

Appendix X: Number of students who passed mathematics in Norway, 2001-2005

(a) Number and percentage of students who passed mathematics and were certified, 1MX and 1MY, in the foundation course, 2001-2005.

Mathematics	2001	2002	2003	2004	2005
Total Number of Students 1MX	12 012	12 426	11 043	11702	12 197
Per cent males 1MX	50.9%	52.4%	53.1%	52.1%	50.5%
Per cent females 1MX	49.1%	47.6%	46.9%	47.9%	49.5%
Total Number of Students 1MY	7287	7632	8706	8219	7920
Per cent males 1MY	31.2%	32.3%	33.1%	33.1%	34.3%
Per cent females 1MY	68.8%	67.7%	66.9%	64.9%	65.7%

(b) Number and percentage of students who passed mathematics and were certified, 2MX , 2MY and 2MZ, in advanced level I, 2001-2005.

Mathematics	2001	2002	2003	2004	2005
Total Number of Students 2MX	6879	7201	7369	7572	7704
Per cent males 2MX	57.4%	58.7%	57.9%	58.1%	56.6%
Per cent females 2MX	42.6%	41.3%	42.1%	41.9%	43.4%
Total Number Students 2MY	2560	2724	139	72	31
Per cent males 2MY	44.7%	47.8%	56.8%	65.3%	58.1%
Per cent females 2MY	55.3%	52.2%	43.2%	34.7%	41.9%
Total Number Students 2MZ	0	31	2824	2914	2883
Per cent males 2MZ	0%	45.2%	42.3%	43%	40.1%
Per cent females 2MZ	0%	54.8%	57.7%	57%	59.9%

(c) Number and percentage of students who passed mathematics and were certified, 3MX, 3MY and 3MZ, in advanced level II, 2001-2005.

Mathematics	2001	2002	2003	2004	2005
Total Number of Students 3MX	4860	4972	5248	5353	5414
Per cent males 3MX	62.5%	63.8%	62.6%	62.7%	60.9%
Per cent females 3MX	37.5%	36.2%	37.4%	37.3%	39.1%
Total Number of Students 3MY	1741	1675	50	16	14
Per cent males 3MY	46.1%	46.8%	46%	42.5%	21.4%
Per cent females 3MY	53.9%	53.2%	44%	37.5%	78.6%
Total Number of Students 3MZ	0	0	1912	2014	2171
Per cent males 3MZ	-	-	41.2%	41.2%	39.7%
Per cent females 3MZ	-	-	58.8%	58.8%	60.3%

A Case Study Research
of
The Policy Implementation Process
in
The Upper Secondary Education System (Senior Cycle)
in
The Sciences and Mathematics in Ireland and Norway

Questionnaire for Principal

April-May 2004

Supporting Documentation: the following documentation would be of great assistance to my case study description of your school

- ☐ School Plan
- ☐ Transition Year Written Programme
- ☐ History/Culture of school (newsletters, etc)
- ☐ Subject Choice Groupings for Leaving Certificate

Questionnaire to be completed by Principal of School*Please note that all the information you supply will be treated as confidential***Section 1: School Profile***(✓ box that applies)***Q.1 School Type**

Voluntary Secondary School	
Vocational School/Community College	
Community School/Comprehensive School	

Q.2 Age of School:

Q.3 Characteristic Spirit or Ethos:

Q.4 Gender Mix (please give the total number of students on the roll for 2003-2004)

Co-educational	
Girls	
Boys	

Q.5 Location

Urban city/town, population > 5,000	
Rural population < 5,000	

Q.6 Size of school

Large > 600 students	
Medium 251-600 students	
Small 1-250 students	

Q.7 Socio-Economic intake (✓ box that applies)

Disadvantaged	
Advantaged	
Mixed	
Working Class	
Middle Class	
Mixed	

Q.8 In your school how is the Junior Certificate Science programme offered (please indicate on table)

Compulsory	
Compulsory, for first years only	
Optional	

Q.9 How are students offered senior cycle subject choices (please indicate on table)

Subject choices are offered as subject groupings which have been pre-determined	Yes	No
Subjects are offered as a list, then the grouping are designed afterward based on demand	Yes	No
By some other route, please give details		

Section 2: Teacher Profile

Q.10 Indicate in the table provided the number of teachers in your school, in each of the following categories:

Teaching Staff 2003-2004	Male	Female
Permanent whole time		
Temporary whole time		
Eligible Part-time		
Part-time teachers		
Guidance Counsellor(s)		
Senior cycle teachers (total)		
Senior Cycle Physics		
Senior Cycle Chemistry		
Senior Cycle Biology		
Senior Cycle Mathematic(s)		

Section 3: Access, Selection and participation in the Sciences and Mathematics 2003-2004

Q.11 Please indicate the number of students who have registered for the Leaving Certificate in the following subjects, for 2003 –2004 and the number taking the subjects currently in fifth year:

PHYSICS	Higher	Level		Ordinary	Level	
	Male	Female	Total	Male	Female	Total
Fifth Year LC1						
Sixth Year LC2						

BIOLOGY	Higher	Level		Ordinary	Level	
	Male	Female	Total	Male	Female	Total
Fifth Year LC1						
Sixth Year LC2						

CHEMISTRY	Higher	Level		Ordinary	Level	
	Male	Female	Total	Male	Female	Total
Fifth Year LC1						
Sixth Year LC2						

Q.12 In your opinion, which of the following (or combination of the following) best describes the student's selection of the science subjects for Leaving Certificate?

In your school by which of the following procedures do students choose TY?	√
Selection for TY	
Self-selection	
Advice from teacher	
By interview	
Advice from Parent(s)/Guardian(s)	
By application	
Advice from Guidance Counsellor	

Q.13 Indicate the number of students you have registered in your fifth and sixth year mathematics class this year (please indicate on table).

MATHEMATICS	Year	Male	Female
Higher level	Fifth Year LC1		
	Sixth Year LC2		
Ordinary level	Fifth Year LC1		
	Sixth Year LC2		
Foundation level	Fifth Year LC1		
	Sixth Year LC2		

Q.14 In your school by which of the following procedures do students choose the three different levels in mathematics (higher, ordinary, foundation)?

Choice of higher, ordinary and foundation level mathematics	√
Advice from teachers	
Advice from parents	
Junior certificate results	
Transition year results	
Own interest	
Advice from Guidance Counsellor	

Section 4: Access, selection and participation in the Senior Cycle Optional programmes 2003-2004

Transition Year (TY)

Q. 15 Indicate the number of students in the transition year programme (please indicate on table).

2003-2004	Male	Female	Total
Transition Year			

Q.16 Is transition year compulsory or optional? (☒ box that applies)

Compulsory ☐

Optional ☐

If optional, by which of the following procedures do students choose TY?

Selection for TY	☒
Self-selection	
Advice from teacher	
By interview	
Advice from Parent(s)/Guardian(s)	
By application	
Advice from Guidance Councillor	

Q.17 Indicate the amount requested for the voluntary contribution per year toward transition year: (☒ box that applies)

☐ < euro 50

☐ euro 50 - 100

☐ euro 100 - 150

☐ > euro 150 -200

☐ euro 200-250

☐ > euro 250

if other (please give details)

Leaving Certificate Applied (LCA)

Q.18 Do you have an LCA programme in your school? (☒ box that applies)

YES ☐

NO ☐

If NO, please indicate reasons

Q.19 Indicate the number of students currently in the LCA programme (please indicate on table)

LCA	2003-2004	Male	Female	Total
Fifth Year LCA1				
Sixth Year LCA2				

Q.20 In your school by which of the following procedures do students choose LCA?

Selection for LCA	√
Self-selection	
Advice from teacher	
By interview	
Advice from Parent(s)/Guardian(s)	
By application	
Advice from Guidance Councillor	

Leaving Certificate Vocational Programme (LCVP)

Q.21 Do you have an LCVP programme in your school? YES ☐ NO ☐

If NO, please indicate reasons

Q.22 Indicate the number of students currently in the LCVP programme:
(please indicate on table)

LCVP	2003-2004	Male	Female	Total
Fifth Year LCVP1				
Sixth Year LCVP2				

Q.23 In your school by which of the following procedures do students choose LCVP?

Selection for LCVP	√
Self-selection	
Advice from teacher	
By interview	
Advice from Parent(s)/Guardian(s)	
By application	
Advice from Guidance Councillor	

Section 5: Structures to support the Sciences and Mathematics

5.1 SCIENCE

Q.24 Please answer the following questions in relation to the structures in your school to support science (☒ box that applies)

Have you a science department? YES ☐ NO ☐

Have you a science Convenor/Coordinator? YES ☐ NO ☐

Do you have a science resource library? YES ☐ NO ☐

Do you have technical support for science? YES ☐ NO ☐

If yes, how many hours per week _____

Do the science teachers meet as a group ? YES ☐ NO ☐

If yes, how many meetings per year _____

Q.25 Indicate the budget amount allocated per year toward science in senior cycle: (☒ box that applies)

☐ < euro 500

☐ euro 500-1000

☐ euro 1000-1500

☐ > euro 1500-2000

☐ euro 2000-2500

☐ > euro 2500

if other (please give details)

5.2 MATHEMATICS

Q.26 Please answer the following questions in relation to the structures in your school to support mathematics in senior cycle (☒ box that applies)

Have you a mathematics department? YES ☐ NO ☐

Have you a mathematics Convenor/Coordinator? YES ☐ NO ☐

Do you have a mathematics resource library? YES ☐ NO ☐

Do the mathematics teachers meet as a group? YES ☐ NO ☐

If yes, how many meetings per year _____

Q.27 Indicate the amount requested for the voluntary contribution per year toward transition year: (☒ box that applies)

☐ < euro 500

☐ euro 500-1000

☐ euro 1000-1500

☐ > euro 1500-2000

☐ euro 2000-2500

☐ > euro 2500

if other (please give details)

Q.28 Do you have a students council?

(☒ box that applies)

YES ☐ NO ☐

If yes, how many meetings per year _____

Do you have a parents council?

YES ☐ NO ☐

If yes, how many meetings per year _____

Section 6: Process issues in the Sciences and Mathematics

6.1 Teaching and Learning

Q.29 Has your school established a school-industry link with the science and technology sector? (☒ box that applies)

YES ☐ NO ☐

If yes, please give details

6.2 ICT Supported Learning

Q.30 Which of the following ICT applications are well established in your school (☒ box that applies)

E-mail

☐

Internet access in the computer room

☐

Internet access in the laboratory

☐

Do the science/mathematics teachers use:

CD-ROM Software

YES ☐ NO ☐ Don't Know ☐

Datalogging equipment

YES ☐ NO ☐ Don't Know ☐

6.3 Assessment

Q.31 Are you in favour of practical examinations in the sciences at senior cycle?

YES ☐ NO ☐

If Yes, what format should they take?

6.4 Evaluation

Q.32 Have you been involved in a whole school evaluation of any of the senior cycle programmes in the last three years?

YES ☐ NO ☐

If Yes, please give details

6.5 Continuing Professional Development

Q.33 Which of the following professional development programmes has your school availed of during 2003-2004: (☒ box that applies)

- SDPI school development planning initiative ☐
- SLSS second level support service ☐
- ICT support service ☐
- Support Service for Physics ☐
- Support Service for Chemistry ☐
- Support Service for Biology ☐

Section 7: Difficulties

Q.34 Have you encountered any difficulties in relation to classroom implementation of the leaving certificate and senior cycle science and mathematics syllabuses and programmes?

(☒ box that applies) YES ☐ NO ☐

If yes, please give details

Q.35 Any other comment you would like to make in relation to the support of the sciences and mathematics in your school

Many thanks for your time and your co-operation.

A Case Study Research

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in

The Sciences and Mathematics in Ireland and Norway

Questionnaire for Physics Teacher

April-May 2004

Physics Teacher Questionnaire

Please note that all the information you supply will be treated as confidential.

Section 1: Teaching Experience and Qualifications

- Q.1 Are you: (✓ box that applies)
Male ☐ Female ☐
- Q.2 How many years have you been teaching? (✓ box that applies)
- | | | | |
|----------------|--------------------------|-------------|--------------------------|
| Probation Year | ☐ | 11-15 years | ☐ |
| 1-5 years | ☐ | 16-20 years | ☐ |
| 6-10 years | ☐ | 20 + years | ☐ |

Q.3 Please state:

Your primary degree _____

Subjects taken in your final year of your primary degree _____

Any further post-graduate qualification/s : _____

Q.4 Are you a member of the local ISTA branch? YES ☐ NO ☐

Section 2: Access, Selection and Participation

- Q.5 Are all students who apply to do physics accepted? YES ☐ NO ☐
- Q.6 Who makes the choice of higher or ordinary level? (✓ box that applies)

Teacher	Student	Both
---------	---------	------

Q.7 Is access to leaving certificate physics determined by:

Junior certificate mathematics results YES ☐ NO ☐

If some other criterion, please give details _____

Q.8 Indicate the number of students you have in your fifth and sixth year physics class this year (please indicate on table).

Subject		Higher	Level		Ordinary	Level	
		Male	Female	Total	Male	Female	Total
Fifth Year	LC1						
Sixth Year	LC2						

Q.9 How many of these students are also enrolled on the LCVP programme?

Section 3: Structures to support PHYSICS

3.1 Science Department

Q.10 How many science teachers in your school? _____

Q.11 Do you meet as a group for planning purposes? YES ☐ NO ☐

If yes, how often? _____

Q.12 Have you ever been involved in an evaluation of your school's science programme? YES ☐ NO ☐

If yes, please give details

3.2 Budget and Laboratory Maintenance

Q.13 Which of the following resources do you have to support the teaching and learning of physics

(✓ box that applies)

An up-to-date Physics library ☐

Technical help in the laboratory ☐

Internet access in the laboratory ☐

Annual budget for the purchase/repair of equipment & resources ☐

Q. 14 If you have an annual budget, please indicate the amount as follows:

☐ < euro 500

☐ euro 500-1000

☐ euro 1000-1500

☐ > euro 1500

3.3 Documentation

Q.15 How often do you consult the following documents?

(✓ box that applies)

	Regularly	Occasionally	Not at all
The Physics syllabus			
NCCA Guidelines			
Chief Examiner's Report			
Physics textbook			
Examination Papers			

Section 4: Process Issues

4.1 Teaching and Learning

Q. 16 Here is a set of statements about the reforms in the senior cycle physics syllabus. Please say whether you

strongly agree agree are neutral disagree strongly disagree

with/about each statement by ticking the appropriate box.

Statement of Reform	Strongly agree	agree	neutral	disagree	Strongly disagree
70% : 30% gives a greater vocational dimension					
Promotes self-directed learning					
Develops critical thinking					
Taught in a "practically and experimentally based way"					
Develops a better school-industry link					

Q.17 In your opinion in what ways does the physics syllabus promote:

(a) Self-directed learning

(b) Critical thinking

4.2 ICT Supported Learning

Q.18 Which of the following ICT applications do you and your students use in the physics classroom: (*✓ box that applies*)

- | | |
|-----------------------|--------------------------|
| E-mail | ☐ |
| Physics web-sites | ☐ |
| Physics Software | ☐ |
| Datalogging equipment | ☐ |

4.3 Assessment

Q.19 Are the current arrangements for the assessment of the mandatory practicals satisfactory YES ☐ NO ☐

If No, please indicate what you think is required to improve the situation

4.4 Continuing Professional Development

Q.20 Which of the following professional development programmes have you availed of: (*✓ box that applies*)

- | | |
|--|--------------------------|
| School visit(s) by the support service | ☐ |
| Physics Inservice Training days (2001-2003) | ☐ |
| Contacted support service this academic year | ☐ |
| The ICT Training course Teach to the Future | ☐ |

Section 5: Difficulties

Q. 21 Have you encountered any difficulties in relation to classroom implementation of the leaving certificate physics syllabus?

(*✓ box that applies*) YES ☐ NO ☐

If yes, please give details

Q.22 Any other comment you would like to make in relation to the teaching of physics in your school

Many thanks for your time and your co-operation.

En case-studie

av

policyimplementeringsprosessen

i

det videregående skolesystemet

i

naturfag og matematikk i Irland og Norge

Spørreskjema for rektor

april-mai 2004

Støttedokumentasjon: *Følgende dokumentasjon ville være til stor hjelp for min casestudiebeskrivelse av skolen din*

- ☐ Skoleplan/virksomhetsplan
 - ☐ Skolens historikk/kultur (nyhetsbrev, etc.)
 - ☐ Adressen til skolens hjemmeside
-

Spørreskjema som skal fylles ut av skolens rektor
Vennligst merk at all informasjon vil bli behandlet konfidensielt

Del 1: Skoleprofil (✓ boks som passer)

S.1 Skolens alder: _____

S.2 Vennligst antyd det totale antall elever ved skolen for skoleåret 2003-2004
 (i tabellen)

Studenter	Mann	Kvinne
Alder 16-19		
Voksne elever		

S.3 Beliggenhet

Urbant, by/tettsted med over 5000 innbyggere	
Mindre enn 5000 innbyggere	

S.4 Skolens størrelse

Stor, mer enn 600 elever	
Mellomstor 251-600 elever	
Liten 1-250 elever	

Del 2: Læreprofil

S.5 Sett inn antall lærere ved skolen, i hver av følgende kategorier:

Pedagogisk personale 2003-2004	Mann	Kvinne
Fulltidslærere		
Deltidslærere		
Timelærere		
Rådgivere		
Matematikklærere		
Fysikklærere		
Kjemilærere		
Biologilærere		

S.6 Hvilke av følgende (eller en kombinasjon av følgende) beskriver best elevenes valg av realfag i den videregående skolen?

Valg av realfag	✓
Selvvalgt	
Veiledning av lærer	
Ved hjelp av intervju	
Råd fra foreldre/foresatte	
Etter søknad	
Veiledning av rådgiver	

Del 3: Strukturer som støtter naturfag og matematikk

3.1 Naturfag

S.7 Hva slags type strukturer har dere etablert for å støtte naturfagene?

S.8 Hva slags mulighet har du som skolens rektor til å vise lederskap i forhold til læreplanene i naturfag?

3.2 MATEMATIKK

S.9 Hva slags type strukturer har dere etablert for å støtte matematikk?

S.10 Hva slags mulighet har du som skolens rektor til å vise lederskap i forhold til læreplanene i matematikk?

S.11 Har dere et elevråd?

(✓ boks som passer)

JA ☐ NEI ☐

Dersom ja, hvor mange møter pr. år _____

Har dere et foreldreråd?

JA ☐ NEI ☐

Dersom ja, hvor mange møter pr. år _____

Del 4: Prosessspørsmål i naturfag og matematikk

4.1 Undervisning og læring

Q.12 Har skolen etablert en skolebedrifttilknytning til teknologi- og vitenskapssektoren? (✓ boks som passer)

JA ☐ NEI ☐

Dersom ja, vennligst spesifiser

4.2 IKT-basert læring

S.13 Hvilke av følgende IKT-applikasjoner er veletablerte på skolen?
(✓ boks som passer)

E-post ☐

Internettilgang i data-/klasserom ☐

Internettilgang i laboratoriet/er ☐

Bruker naturfag/matematikklærere:

Programvare på CD-ROM JA ☐ NEI ☐ Vet ikke ☐

Datasamlingssutstyr JA ☐ NEI ☐ Vet ikke ☐

4.3 Vurdering

S.14: Er du fornøyd med vurderingssystemet slik det fungerer i naturfag og matematikk i dag?

JA ☐ NEI ☐

Dersom NEI, hva vil du anbefale?

4.4 Evaluering

S.15 Har du vært involvert i evalueringen av naturfag/matematikkprogrammene i skolen som helhet i de siste tre årene? JA ☐ NEI ☐

Dersom ja, vennligst spesifiser

4.5 Fortsatt profesjonell utvikling

S.16 Hva slags profesjonelle utviklingsprogrammer har vært til nytte for skolen i forhold til læreplanene i naturfag og matematikk i 2003-2004:

Del 5: Vanskeligheter

S 17 Har du støtt borti problemer i forhold til gjennomføring av naturfag- og matematikkfagplanene i klasserommet?

(✓ boks som passer)

JA ☐ NEI ☐

Dersom ja, vennligst spesifiser

S.18 Andre kommentarer du vil gi i forhold til naturfag og matematikk ved din skole

Mange takk for samarbeidet og at du satte av tid til denne undersøkelsen.

En case-studie

av

Policyimplementeringsprosessen

i

det videregående skolesystemet (VKII)

i

naturfag og matematikk i Irland og Norge

Spørreskjema for fysikklærere

april-mai 2004

Spørreskjema for fysikklærere

Vennligst merk at all informasjon vil bli behandlet konfidensielt.

Del 1: Undervisningserfaring og kvalifikasjoner

- Q.1 Er du: (✓ boks som passer)
Mann ☐ Kvinne ☐
- Q.2 Hvor mange år har du undervist? (✓ boks som passer)
- | | | | |
|----------|--------------------------|---------------|--------------------------|
| Prøvetid | ☐ | 11-15 år | ☐ |
| 1-5 år | ☐ | 16-20 år | ☐ |
| 6-10 år | ☐ | mer enn 20 år | ☐ |

- Q.3 Vennligst angi:
- Din grad _____
- Emner som ble studert i siste år av gradsoppnåelsen
- _____
- Etter-/videreutdanning: _____

- S.4 Er du medlem av en lokal fysikklærerforening?
- JA ☐ NEI ☐

Del 2: Tilgang, utvalg og deltagelse

- Q.5 Blir alle elever som søker på fysikk tatt opp? JA ☐ NEI ☐
- Q.6 Hvordan blir adgang til studieretningstilbudene på VKI og VKII bestemt? (✓ boks som passer)

Av lærer	Av elev	Av matematikkresultatene
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Dersom andre kriterier, vennligst spesifiser

- Q.7 Antyd antall elever du har i dine fysikklasser dette skoleåret (vennligst benytt tabellen).

Fysikk	Modul	Mann	Kvinne
VKII	3FY		
VKI	2FY		
Grunnkurs	Naturfag & matematikk		

Del 3: Strukturer som støtter FYSIKK

3.1 Naturfagseksjonen

- Q.8 Hvor mange realfagslærere er det på din skole? _____
- Q.9 Møtes dere som en gruppe for planlegging? JA ☐ NEI ☐
- Dersom ja, hvor ofte? _____
- Q.10 Hvor mye tid er tildelt hvert møte? _____
- Q.11 Har du noensinne vært involvert i evaluering av skolene realfagsprogram?
JA ☐ NEI ☐
- Dersom ja, vennligst spesifiser _____

3.2 Budsjett og vedlikehold av laboratorier

- Q.12 Hvilke av følgende ressurser har du til å støtte undervisningen og læringen i fysikk
(✓ boks som passer)

- Oppdatert fysikkbibliotek ☐
- Teknisk hjelp i laboratoriet/er ☐
- Internettilgang i laboratoriet/er ☐
- Årlig budsjett for kjøp/reparasjoner av utstyr og ressurser ☐

- S.13 Dersom du har et årlig budsjett for fysikk, vennligst indikerer hvor stort:

- ☐ < 500 Euro ☐ 500-1000 Euro
- ☐ 1000-1500 Euro ☐ > 1500 Euro

Dersom annet beløp, vennligst spesifiser _____

3.3 Dokumentasjon

S.14 Hvor ofte konsulterer du følgende dokumenter?

(✓ boks som passer)

	Jevnlig	Nå og da	Aldri
Fagplan for fysikk			
Dokumenter fra departementet			
Læreboken i fysikk			
Eksamenspapirer			
Annet (vennligst spesifiser)			

Del 4: Prosessspørsmål

4.1 Undervisning og læring

S. 15 I hvilken grad blir følgende undervisningsmetoder/aktiviteter brukt i fysikkundervisningen? (✓ boks som passer)

	ofte	Nå og da	sjeldent	aldri
Gruppearbeid				
Utspørring/høring				
Eksperimenter				
Utforskningsarbeid				
Bruk av datamaskiner				
Prosjektarbeid				
Tavleundervisning				
Utendørsekskursjon				

S.16 I hvilken grad fremmer, i følge deg, fysikkfagplanen:

(a) læring rettet mot enkelteleven

(b) Kritisk tenking

4.2 IKT-basert læring

S.17 Hvilke av følgende IKT-applikasjoner bruker du og elevene i fysikklaboratoriet?

(✓ boks som passer)

- E-post☐
- Fysikkhemmesider☐
- Programvare for fysikk på CD-ROM☐
- Datasamlingssutstyr☐

4.3 Vurdering

S.18 Fører elevene journal/logg som en hjelp for kontinuerlig vurdering?

☐ JA \ NEI ☐

S.19 Basert på hvilke kriterier blir terminkarakterene satt for den delen som gjelder for klassen som helhet? (evner, holdninger, kunnskap, andre)

S.20 Standpunktkarakteren i fysikk er basert på arbeidet i klassen og eksamen. Hvilken fordelingsnøkkel brukes for hver av delene?

☐ arbeid i klassen

☐ Eksamen

S.21 Gjør elevene ferdig prosjekter i fysikk?

☐ JA NEI ☐

S.22 Hvilke ressurser har du til å støtte undervisningen av prosjektarbeid i fysikk?

4.4 Fortsatt profesjonell utvikling

S.23 Hva slags profesjonelle utviklingsprogrammer har du deltatt på dette skoleåret som støtter fysikkundervisningen?

Del 5: Vanskeligheter

S. 24 Har du støtt borti problemer i forhold til gjennomføring av fysikkfagplanene i klasserommet?

(✓ boks som passer)

JA ☐ NEI ☐

Dersom ja, vennligst spesifiser

S.25 Andre kommentarer du vil gi i forhold til undervisningen av fysikk ved din skole

Mange takk for samarbeidet og at du satte av tid til denne undersøkelsen.