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From the Drawing Board into Schools:

An Analysis of the Development and Implementation of a New Physics Curriculum in New Zealand Secondary Schools

A thesis

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by

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*“Weep not that the world changes –
did it keep a stable changeless state,
‘twere cause indeed to weep.”*

in ‘*Mutation*’

by William Cullen Bryant (1794-1878)

ABSTRACT

This thesis explored the introduction of a new physics curriculum in New Zealand secondary schools. It was part of a nationwide overhaul of the whole school curriculum from primary to secondary schools, initiated in the early 1990s.

The study of curriculum change is inextricably woven with teacher change, as the teacher is seen as central to any real change in curricula in the classroom. Some theories of teacher change are reviewed here and synthesised into a list of criteria relevant to bringing about effective change in teachers and their practices.

A sociocultural perspective emerged as being a useful theoretical approach in analysing and explaining these processes of curriculum change and teacher change because it takes a holistic approach that deals with 'people, places and things' and the discourses involved therein. In particular, Wenger's sociocultural theory was used to study the introduction of a new senior physics curriculum. His terms "reification" and "participation" were seen to apply to this research: the curriculum document was taken to be a reified communication artifact, and "participation" is involved in every stage of its development and implementation.

In the context of this theorising, data was procured from in-depth interviews with the three curriculum writers and ten physics teachers in and around a provincial city in New Zealand. The teachers were interviewed three times over a period of three years: before, during and after the first year of implementation; namely 1996 to 1998.

The interviews showed that most of these ten physics teachers did not undergo any significant change in their teaching because of the introduction of *Physics in the New Zealand Curriculum*. The reasons or barriers identified, such as lack of guidelines and clarity, and contentment with their own existing practice, were aligned with factors that have been identified by other researchers as important influences on teachers undergoing change, such as clarity of change and need for change.

Three key elements were identified from these issues emerging from the data as necessary conditions or resources for teacher change: knowledge, support and time. In

the present study, there was very limited knowledge held by the teachers about ‘what’, ‘how’ and ‘why’ changes were being implemented. Secondly, there was little social and system support for the curriculum change. Finally, teachers had little time to focus on and reflect on the change.

A model of curriculum change, incorporating Wenger’s notions of “reification” and “participation”, but extended to include “dereification” emerged from the data. "Dereification" highlighted an important stage whereby the curriculum document as an artifact, needed to be incorporated into the plane of lived experiences of teachers. The introduction of the term "dereification" supported the development of this model of curriculum change incorporating teacher change whereby the model outlined processes of reification and dereification involved in a mandated curriculum change. The model of curriculum change developed here also contained a screen that symbolises the lack of intersubjective linkage between teachers and the designers of the new curriculum. There was no follow-up teachers’ guide, not enough explanation of the curriculum document, no direct communication between the writers and the teachers, and insufficient professional development for the teachers using it.

The research findings led to three propositions: the curriculum document as a key artifact was not sufficient to effect a curriculum change; the lack of transparency of the curriculum document development was a constraint on teachers’ commitment to the curriculum change; and the lack of support for teachers in their dereification of the curriculum document impacted negatively on curriculum change.

The key elements of knowledge, support and time identified as crucial for teachers to effect any real change in their practice are critical at different points in the model of curriculum change. It is suggested that using such an interplay between the factors underlying teacher change and the sociocultural analysis of curriculum change, might enable more pro-active intervention at the various stages of the process of a curriculum change to effect a real change.

Publications arising from this thesis

Refereed Journal Articles

Fernandez, T. S., & Ritchie, G. (2003). Analysing pedagogical change: Physics teachers' responses to a new curriculum. *Waikato Journal of Education*, 9, 91-111.

Fernandez, T. S., Ritchie, G. & Barker, M. (in press). A sociocultural analysis of mandated curriculum change: The implementation of a new senior physics curriculum in New Zealand schools. *Journal of Curriculum Studies*.

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It is finally completed; an impossible dream that at times I had wondered whether it would ever end. But of course when surrounded by so much support and goodwill, it is made possible. Now, as I reach the end of this academic ride, I want to acknowledge the wonderful people who supported me through it all.

First and foremost, I will mention my husband Garth, my support and my critic. As a support, he carried the extra burden of household chores and child-minding to free me to do the thesis. As a critic, he was my unofficial third supervisor; one who was available ‘any time’ of the day and night. How fortunate can a PhD student be if she can have her thoughts clarified, writing scrutinised and ideas debated when cooking dinner or having breakfast or pottering in the garden!

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As for Associate Professor Miles Barker, I shall not forget the day when I began to see the ‘light at the end of the tunnel’ when he took my rough model of curriculum change and breathed his contribution on it – the analogy of the nitrogen cycle. The example was a great help for me to start refining the rough model to what it looks like now in Chapter 10. In many ways Miles has so effectively kept me going on the right path; without compromising on standards, he knew when to prod me on gently and when to leave me for awhile to find my own ground. He has been very instrumental to getting me going when I was hitting my lowest point. Not many PhD students can speak of supervisors who turn up at their doorstep to give feedback and encouragement. That was incredible support!

Now I must speak of my ten teacher participants and the three writers of the physics curriculum. Not only did they give so much of their precious time in their busy schedules, but I was humbled by the way they were willing to open up and share deeply of their experiences and of themselves.

On the 23rd of December 1998, I did my final data collection interview and, on that same day, I received the bad news of a life-threatening illness that needed an urgent operation. After surviving this ordeal and being told to reduce stress levels, the obvious thing that most people felt I needed to let go was the thesis. But I had a burning desire to tell the stories of these wonderful participants of my research. The sharings by the writers and teachers were so profound; I found echoes of that in literature written thirty years ago right up to literature still being written today. Their stories seemed to transcend time and space, and speak to the heart of curriculum change.

Next I want to acknowledge family and friends. So much prayer and goodwill were sent my way and I could sense them in the final months of the report write-up. Thank you Mum for saying that you are not coming to visit me this year (she lives overseas)

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Yes, I feel blessed, truly blessed: despite some very difficult circumstances, I have finally had the joy of completing this thesis. I feel good about it; I enjoyed putting it together; and I stand by what I have written in it. I place it with gratitude at the feet of God, Jesus and His Mother Mary, who have kept my spirit and hopes afloat when dire situations overtook me. This thesis I now place in your hands and I hope you enjoy reading it and are enriched by the ideas that unfold within its pages.

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Chapter 1 ➤ Introduction

1.1 Rationale and Elaboration

Political and economic changes in society impinge on schools making it imperative for the curriculum to keep up with the trends. The changes in the schools can be just small scale tinkering to the existing system such as tying up loose ends, dealing with trouble spots, incorporating new ideas or feedback, or the changes could be major upheavals affecting every aspect of the school curriculum. Right through the 1990s and into the next decade, New Zealand underwent a major nationwide school curriculum restructuring starting from changes to educational policy, to curriculum development and to its implementation. The origins of these changes were undoubtedly political (see O'Neill, 1997) and the full impact on the school curriculum is the subject of study by a number of researchers (e.g., McGee, Jones, Cowie, Hill, Miller, Harlow & Mackenzie, 2003).

The scenario was set for the impact of these new initiatives on the direction of teaching and learning of physics in the classroom. A new physics curriculum document, *Physics in the New Zealand Curriculum*, was published in 1994 and, as a consequence, there were new forms of physics assessment. The teacher was a critical component in these nationwide curriculum changes and this was an exciting period of change and redefinition for physics teachers in New Zealand secondary schools.

In the field of curriculum, the development and implementation of a curriculum are often studied separately because of the usually long time frame of each phase. However, Goodson (1994) suggested that research into the bigger picture of both curriculum development and its implementation, considered jointly, would be very useful. With the relatively short time span designated for the curriculum changes in the 1990s for New Zealand schools (development for the physics curriculum initiated in 1993, promulgation in 1994, and its implementation by 1998), an opportunity arose for me to study the development and early stages of implementation of a new physics curriculum in New Zealand secondary schools. The timing of data collection in my research straddled the period two years after the publication of *Physics in the New*

Zealand Curriculum and into the first year of mandatory implementation of the new physics curriculum in all secondary schools in New Zealand (i.e., from 1996 to 1998). Thus the memories of the writers of the curriculum document about the process of development of the new curriculum were still fresh, and teachers were in the process of grappling with the new curriculum and working towards implementing it in their classrooms.

In embarking on this research, I hoped that the findings from such a study would be relevant for curriculum policy makers and for those planning teacher development programmes for curriculum change. It was also intended to give teachers and those aiming to become teachers an insight into the making of a curriculum and thus, possibly, empowering them to analyse their practice in the light of these insights (Goodson, 1994).

1.2 Background of the 1990s Curriculum Changes in New Zealand

Unlike many Western countries where the emergence of a national curriculum is a recent phenomenon (Sharp & Grace, 2004), New Zealand has had a national curriculum at least since 1950s, for example, in the *Thomas Report* (Department of Education, 1959).

In 1984, with the appointment of Russell Marshall as Minister of Education under the newly elected fourth Labour government, a committee was set up to review the curriculum for schools. This led to a huge consultative endeavour encompassing a wide range of people and their views. The result was the production of two policy documents: *The Curriculum Review* and *The Draft National Curriculum Statement* (Department of Education, 1987, 1988a). The key features of these documents were a national curriculum to be developed for all schools and each school to take the responsibility to develop a school curriculum consistent with the national common curriculum. The focus was on the individual learner and curriculum was interpreted as everything involved in a school's learning programme which includes all activities, events and experiences (Bell, Jones & Carr, 1995).

The science curriculum for students aged 11 to 14 years was revised, taking into account the main themes of *The Curriculum Review*. The existing syllabus based on behaviourist and hierarchical views of learning was found to be too content-based and a new science syllabus implicitly based on the personal constructivist view of learning (Osborne & Freyberg, 1985) was drawn up in 1989 (Department of Education, 1989; Bell, 1990) for the Forms 1-5 science curriculum.

However, at this time, radical shifts in administration of public education were being advanced by the *Picot Report* (Department of Education, 1988b) and *Tomorrow's Schools* (Department of Education, 1988c). The involvement of the Treasury in this debate was built around the neoliberal ideas that facilitating the market behaviour of individuals should be given priority as it helped to develop a healthy and efficient economy (McKenzie, 1999). The decentralisation of school administration and the setting up of self-managing schools, each with their Board of Trustees and school charter, have been the mainstay of public education in New Zealand since the *Picot Report*.

The Curriculum Review and *Draft National Curriculum Statement* came under fire; they were especially criticised for focusing on the individual learner and not addressing issues such as education contributing to the needs of society (Levett & Lankshear, 1990), and overlooking issues such as community and educational values, education and the economy (Codd, 1993). These criticisms reflected the immense social, political and economic changes happening in New Zealand at that time (Boston, 1991). These changes with their neoliberal underpinnings moved the New Zealand educational-political landscape to the right with the election of a National Party government in November 1989. The new Minister of Education, Lockwood Smith, inspired by the New Right notions of education in Britain, set about a major curriculum reform in primary and secondary schooling in New Zealand calling it the "Achievement Initiative" (Ministry of Education, 1991). He compromised the autonomy of self-managing schools by introducing curriculum reforms that called for much tighter central official curricular specifications with clearly specified standards of attainment (McKenzie, 1999). The ethos of the original curriculum change based on *The Curriculum Review* was thrown into disarray and the focus shifted to viewing education as an economic commodity (Bates, 1990).

The New Zealand Curriculum Framework (Ministry of Education, 1993a) was drawn up as an umbrella document that set out “the foundation for learning programmes in New Zealand schools for the 1990s and beyond ... the foundation policy for learning and assessment in schools” (p. 1). A series of supporting documents for the various subject areas were formulated and defined as the national curriculum statements. One of these was *Science in the New Zealand Curriculum* (Ministry of Education, 1993b; Haigh, 1995). An important feature of the development of these statements was that the Curriculum Development Division at the Ministry of Education had been dismantled and curriculum development was contracted out to experts in the respective subject areas.

A major criticism levelled at these curriculum statements was the specification of the aims and objectives in behavioural terms; breaking the subject down into discrete prescribed tasks that are easily measured against standards (Peters & Marshall, 1996). Neyland (1995) argued that the curriculum statements having achievement objectives are based on principles of neo-behaviourism. He warned that it would lead to neo-behaviourist approaches to pedagogy where a mechanistic approach is adopted in teaching with the emphasis on outputs and the assessment of the achievement of objectives. He suggested that the holistic and more social constructivist approaches to pedagogy would be undermined.

In 1994, the *Physics in the New Zealand Curriculum* statement was published by the Ministry of Education. This document was a culmination of work by curriculum writers contracted by the Ministry of Education. It was a statement of what physics education for Years 11 to 13 at senior secondary schools should entail. Discussions and submissions based on a draft document, circulated in 1993, were incorporated into the final document. In the foreword to this document, the then Secretary for Education, Dr Maris O'Rourke, indicated that full implementation of the new physics curriculum would take place from 1997 (that was later postponed to 1998; the delay due to a moratorium on the school curriculum reform because of strike action by the Teachers' Union in 1996).

While all these curriculum changes were beginning in 1990, the New Zealand Qualifications Authority (NZQA), an independent statutory body, was established. It was part of the Skill NZ initiative set up to develop a National Qualifications

Framework. Part of its function was to develop Unit Standards (a new standards-based assessment) and new examination prescriptions that would take care of the summative assessment for Years 11 to 13 for the senior school subjects, such as Physics. The achievement aims and objectives of the new curriculum subject statements as documented by the Ministry of Education were to be used as a basis for these new forms of assessments.

Science in the New Zealand Curriculum had been developed in a consultative manner and there were avenues for various interests groups to have their say. The physicists, represented by the Institute of Physics, were not satisfied with the coverage of physics in the science document and they pushed for a separate senior physics document. This led to the development of individual documents for the senior sciences (physics, chemistry and biology), one of which was *Physics in the New Zealand Curriculum* (Ministry of Education, 1994).

The research reported in this thesis focuses on the development of *Physics in the New Zealand Curriculum* (PitNZC) and the impact it had on physics teachers in New Zealand. As the curriculum document was central to this curriculum change initiative, the following section is dedicated to presenting it in further detail.

1.3 The Physics in the New Zealand Curriculum Document

Physics in the New Zealand Curriculum was initially promulgated as a 42-page draft booklet in 1993, and as a final 47-page document in 1994. For both the draft and the final documents, the main feature is the separating of the physics curriculum into three levels, Levels 6, 7 and 8. In the final document, each of these levels contained sections on Achievement Objectives with content that are to be included at that level, Sample Learning Contexts, Possible Learning Experiences and Assessment Examples for each objective (see Appendix A1). The Achievement Objectives at each level were based on the three aims (or strands) of the physics curriculum (see Appendix A2). The three strands identified as aims for students in physics education were understanding physics concepts, principles and models; appreciating the nature of physics theories and the impact of physics on society; and developing practical investigative skills and attitudes. These achievement aims encapsulate the three important areas in the

teaching and learning of physics and were expected to be integrated in the teaching programmes.

The practical aspect of learning physics was expanded in a separate section titled *Developing Investigative Skills and Attitudes in Physics* (see Appendix A3). This section followed the structure set out by *Science in the New Zealand Curriculum* where four main areas of skills with their associated achievement objectives were identified: focusing and planning; information gathering; processing and interpreting; and reporting. Examples of what could be done to teach the various skills were set out under Possible Learning Experiences related to the various skills (see Appendix A4).

The beginning pages of the physics curriculum document outlined the purpose of physics education (see Appendix A5); approaches to teaching and learning in physics (see Appendix A6); development of essential skills (see Appendix A7); the language of physics; the place of mathematics in physics; safety; guidelines to the format and interpretation of the physics curriculum; and the general achievement aims. Comments were included in the physics document to link up with *Science in the New Zealand Curriculum* and the *New Zealand Curriculum Framework*.

The philosophy of *Physics in the New Zealand Curriculum* was contained in the first few pages under 'introduction' and the 'purpose of physics education' and in the section on 'approaches to teaching and learning in physics'. The document contained many examples that were not intended to be prescriptive, on how to put the objectives into action in the classroom, and there was a range of activities "from tightly defined tasks to broad investigations" (Ministry of Education, 1994, p. 26).

There was a degree of consultation for *Physics in the New Zealand Curriculum*. The draft document was circulated to all secondary schools nationally in New Zealand and to other interested organisations and individuals inviting submissions before the final document was written.

The structure of the final document was essentially similar to the draft with an additional lift-up page at the end that summarised the achievement objectives, content, and investigative skills for the various levels at a glance. A new section on the "purpose of physics education", with six bullet points, was added to the

“introduction” page (see Appendix A5). A section on the “development of essential skills” as outlined in the *National Curriculum Framework* was added with its interpretation for physics (see Appendix A7). Sections on “language of physics” and “safety” were also added. However the main change that occurred in the final document was the tying up of the levels with compulsory and optional content areas in physics. This outcome was due to the hue and cry that erupted when the physics contents were tied loosely to each level in the draft physics document with the comment that those topics “could” be included at that level. The lack of specificity in that suggestion was not supported especially by physics teachers and this was evident in their submissions.

There was also a re-arrangement of the achievement objectives where Objective 1 was interchanged with Objective 3 (i.e., the order of the aims in the draft and the final documents were different); and a re-wording of the objectives. It was noted that Objectives 1 and 3 had similar wordings for the different levels as their level of difficulty was differentiated by the content or topics given for the different levels. The achievement objectives for investigative skills for the different levels were dealt with in the final pages of the final document.

This descriptive analysis of *Physics in the New Zealand Curriculum* is based on comparing the draft document with the final document. It provides the backdrop to understanding the comments of the writers of the document and also those of the teachers using the document reported in this thesis. A deeper and more insightful interpretation of the document will be presented in Chapters 5 and 6 which deal with the comments from the writers of the document.

1.4 My Focus and Background

I am a physics teacher who has also done research into science education especially in the area of innovative beginning teachers. As a physics teacher, I have experienced a sense of isolation and being left to my own devices. In-service courses once or twice a year were not supportive enough of my teaching especially when I wanted to try some new pedagogical innovation. However, in school, I was viewed as an expert in my subject area because physics is a field where the other teachers on the staff could not relieve or support. Compared to core subjects, physics is not a widely chosen subject

by students; the numbers are limited and many schools have only one physics teacher. The sense of isolation persisted even when I was teaching in a syndicate of three physics teachers. This prompted me to want to see how other teachers taught physics.

The draft of *Physics in the New Zealand Curriculum* encouraged the physics teachers to get together in groups to discuss and make submissions. I got together with a group of physics teachers but I made a submission as an individual teacher. My submission highlighted the pitfalls of not prescribing content. In hindsight, I realise that though it was a concern of mine at that time, it probably was an unenlightened submission because I was unaware, apart from what was written in the draft document, of what were the main intentions behind the draft physics curriculum.

With this background, I was very interested in how the physics curriculum was developed, what the key changes intended by the curriculum developers were, and also what actually happened in the implementation of the new curriculum. In particular, I was interested in how teachers changed in their pedagogy, especially since I believe that despite having spent much time, effort and money in developing a curriculum document, if teachers do not change what they do in the classroom, the curriculum change remains merely a 'paper artifact'. The curriculum changes of the 1990s gave a good opportunity to pursue this interest. The timing of the development and implementation of the physics curriculum change enabled a study that could span this wide area. In the past, most studies had to concentrate on either the development or the implementation of curriculum change (Goodson, 1994). The possibility of studying both areas in one research project was exciting and formed the basis of this thesis.

The aim of this research is to explore the development of *Physics in the New Zealand Curriculum* and to follow it through to the implementation in schools of the new physics curriculum outlined in the document. The approach taken in this exploration is of investigating insiders' perspectives of the processes involved in the development and implementation of a new curriculum.

1.5 Overview of Thesis Chapters

Chapter 2 reviews the literature on the two main themes of this research: curriculum change and teacher change. Chapter 3 explains the theoretical perspectives that underpin this research, in particular, sociocultural theories, especially Wenger's theory of communities of practice. It also lays out the research questions to be explored in this thesis. Chapter 4 looks at the choice of the research methodology used in this research, and introduces the structure of the research and the participants. It also gives an indication of how the data was analysed and discusses the relevant reliability and validity issues or their equivalent. Chapters 5, 6, 7, and 8 detail the data collected in the research. These chapters contain the writers' views, case studies of two teachers, and a summary of the ten teachers' views. Chapters 9 and 10 analyse the data in more depth. Chapter 9 ties the data analysed with the literature reviewed on teacher change and leads the discussion to some conclusions regarding effective teacher change. Chapter 10 uses the data analysed to build a bigger picture of curriculum change. Here, a model of mandated curriculum change is developed based on the extension of Wenger's notions of reification and participation, and an added concept of 'dereification'. Finally, Chapter 11 summarises the answers to the research questions and discusses some propositions that arose from this research. It also highlights the value of the model of curriculum change developed, the limitations of the research, and draws conclusions and implications for future curriculum development and implementation projects.

Chapter 2 ➤ Literature review on Curriculum Change and Teacher Change

2.1 Introduction

The literature about curriculum change and teacher change is enormous. Almost every country, every school, and many teachers and students have contributed to the ideas, findings and research in this all-important area of education. In a curriculum change situation teachers mostly function in the capacity of implementers of a new programme or curriculum in their classrooms, although some might be involved in action research or be writers of new programmes, or even be leading teacher development for the new programmes. This chapter will deal with some of the relevant literature on curriculum and teacher change especially when teachers have to change their pedagogies when faced with a change in curriculum.

2.2 Curriculum and Curriculum Theory

Firstly, in this section, the various conceptualisations of curriculum are explored. It is difficult to get a consensus on the ‘definition’ of curriculum as each curriculum theorist gives a definition based on their particular philosophical stance. These stances lie somewhere along a continuum from curriculum being considered a prescription of contents to a holistic view that includes the socio-political influences on schooling.

Schubert (1986) in describing the extent of this continuum evades the whole issue of definition by claiming that to define curriculum would be to restrict the richness of understanding of this complex field. He prefers to describe curriculum in terms of its major conceptions: curriculum as content or subject matter, curriculum as discrete tasks and concepts, curriculum as a program of planned activities, curriculum as intended learning outcomes, curriculum as cultural reproduction, curriculum as experience, curriculum as an agenda for social reconstruction, and curriculum as “currere” (a Latin word meaning ‘the course to be run’). The last conception views curriculum as a process of reconceptualisation by individuals of their perspective of

life based on autobiographical accounts that encompass the past, present and give direction for the future.

It also becomes a social process whereby individuals come to greater understanding of themselves, others, and the world through mutual reconceptualisation. ... The curriculum is the interpretation of lived experiences. (Schubert, 1986, p. 33)

This mutual reconceptualisation not only refers to interactions between people in immediate proximity, but includes learning interactions through books, other literary and artistic expression, and other means. Any particular curriculum, such as that proposed by *Physics in the New Zealand Curriculum*, will encompass some aspects of all these major conceptions put forth by Schubert.

Another definition of curriculum is given by Stenhouse (1975) who describes it as a link between educational principles and educational practice:

A curriculum is an attempt to communicate the essential principles of an educational proposal in such a form that it is open to critical scrutiny and capable of effective translation into practice. (Stenhouse, 1975, p. 5)

This view however is repudiated by Kemmis and Fitzclarence (1986) who note that theory and practice cannot be separated out as distinctive domains as they mutually affect each other and together constitute the meaning of education. They point out that curriculum theory needs to address two important problematic issues: the relationship of theory and practice, and the relationship of education and society. They suggest that the role of society in education cannot be underestimated. The different views and values in society will be fiercely contested by the stakeholders as a curriculum change is initiated:

... the choice of what aspects of the life and work of a society should be represented in the curricula of its schools and other educational institutions remain crucial, not only to educationists but to society as a whole. (Kemmis & Fitzclarence, 1986, p. 23)

The historical perspective on curriculum change as described by Goodson (1988) aligns with the views of Kemmis and Fitzclarence (1986) when he concludes that curriculum should be viewed as a social and historical construction, and should be studied with the sensitivity that such an understanding requires.

Just as there are many ways of defining curriculum, there are many ways in which curriculum theory can be categorised. For example, Kemmis and Fitzclarence (1986) use the categories of technical, practical and critical as different views of curriculum theorising. Schubert (1986) uses the categories of descriptive, prescriptive, critical, and personal conceptions of curriculum theory. A number of other sets of categories have been espoused by various curriculum theorists (e.g., Wraga & Hlebowitsh, 2003). Each category has its own particular stance of theorising curriculum. However, Morrison (2004) argues that it is limiting to look for a singular theory of curriculum. He advocates multiple theories that delimit the curriculum. He says that there is no such thing as a value-free curriculum theory as he views curriculum as a site of social engineering. Certain interests are protected, acknowledged and advanced by selecting what goes into a curriculum from culture, knowledge and society. However he wants to throw off that yoke of control of any particular curriculum theory and set curriculum free:

Curriculum theory should be a theory of plenitude, of excitement, of abundance, of the creation and discovery of new ideas. ... the curriculum is what we learn, what we do, what we think, what we value, what we are, who we are, and who we want to be, both as persons and as communities. (Morrison, 2004, p. 492)

Another conception of curriculum that is useful to consider here is the technocratic versus the critical curriculum by McGee (1997). By technocratic, he means the curriculum as defined by physical entities such as curriculum documents which usually include syllabuses, teachers' handbooks, other resource and teaching materials, and assessment materials. Here the curriculum is seen as a plan for teaching and decontextualised from the policy making and even the contexts of its implementation. The danger as described by McGee is that such a view regards curriculum to be neutral and beneficial to all; the prime goal being the learning of an "uncontested body of knowledge" (p. 46). This limited conception of curriculum is in stark contrast to that liberating view advocated by Morrison (2004). On the other hand McGee advocates another way of viewing the curriculum: the critical perspective. Here the curriculum is more than a set of plans for teaching; it includes both practice and plans. The context of building the curriculum, in terms of the planning and implementation features that affect the curriculum, need to be open to teachers and students so that they may be able to deal with the curriculum more reflectively. Thus a

critical curriculum is seen as more open-ended and less prescriptive than a technocratic curriculum. The two conceptions advanced by McGee can be compared to the two ends of the continuum of conceptions of curriculum described earlier in this section that range from curriculum being a prescription of contents to curriculum being a more holistic view of education including the socio-political influences on schooling.

In this research, curriculum is viewed as involving the physics curriculum document which encompasses the political, philosophical, psychological and subject discipline agendas, as well as involving the social contexts of teachers and their classrooms. Thus the printed document contains injunctions about purposes, pedagogy and content for physics teachers to use in classrooms. There are underpinning social, political and cultural ramifications but in this research report, reference to the “new curriculum” refers to the implications of the ideas presented in *Physics in the New Zealand Curriculum*. Curriculum development in this research report refers to the production of *Physics in the New Zealand Curriculum* which is clearly seen not to be a simple linear process as advanced by Tyler (1949) but one that is engulfed with underlying complexities covered in Chapters 5 and 6.

An understanding of what ‘curriculum’ is and its many facets as shown in this section can lead to a better appreciation of curriculum change. Curriculum as a social, cultural and historical based entity cannot be static because its bases are not static. This leads inevitably to curriculum change which is explored further in the next section.

2.3 Curriculum Change

The school curriculum, or the national curriculum from which the school curriculum is derived, is tied closely with the needs of society. As society is in a continuous flux of change, it is inevitable that the school curriculum will have to change from time to time to keep up with societal changes. In New Zealand there seems to be a curriculum change recorded roughly every ten years.

The process of curriculum change can take many paths and this has been illustrated by the different models that have been employed in New Zealand; for example, the centrist model (a top-down model with research and drafting of documents before

official implementation); centre to periphery model (change carried out by a committee made up of representatives of interest groups in the subject area); research, development and dissemination model; and action research (Bell, 1990; McKinley & Waiti, 1995). One characteristic that distinguishes the different models is the level of negotiation of the curriculum change with the centrist model having the least amount of negotiation with the teachers and the action research model having the most.

Examples of more cooperative models of curriculum change where there is greater negotiation with teachers are described in Baird, Mitchell & Northfield (1987), Pedretti and Hodson (1995), Elmore (1995), and in Prawat (1996). These can be contrasted with the top-down model of curriculum development employed in the 1990s curriculum changes in New Zealand.

Often a top-down curriculum change is initiated in two stages: writing of curriculum documents, termed in this research as curriculum development, and curriculum implementation which includes developing school plans for learning. Research so far has tended to study each stage separately in great depth and important findings have emerged. However, there is a need to analyse curriculum change in its broader and more complete picture. This is supported by Goodson (1994) and Schubert (1986). Schubert extends the role of curriculum developer from merely developing curriculum documents to encompass the work of teachers as he considers them as having a key role in developing curriculum in their planning of programs that influence the knowledge, skills, attitudes and values of their students. He contends that their effectiveness in this role can be enhanced by informing them of research and theory that support the curriculum development process.

This research will explore curriculum change that was initiated by the Minister of Education, that is, from the top, and follow the curriculum development to the stage of implementation where the impact of this curriculum development on physics classrooms is studied. One important factor in this situation of a curriculum change is the teacher. Without the teachers changing their practice, there can be no real change in the school curricula. This is the topic of discussion in the following section.

2.4 Teacher Change

Curriculum change implies teacher change. The critical role of teachers in any curriculum change process is acknowledged by many writers on school curriculum (e.g., Bates, 1991; Bell & Gilbert, 1996; Butler & Beasley, 1988; Claxton & Carr, 1991; Davis, 2002; Elmore, 1995; Fullan, 1987; Schubert, 1986; Shulman & Sherin, 2004; Waugh & Punch, 1987). The high expenditure of time and resources in developing a glossy curriculum package can be a waste if teachers are not empowered to effectively implement the new curriculum in their classrooms. Teacher development leading to teacher change is therefore seen as crucial in facilitating the implementation of a new curriculum. Literature on teacher development covers the various strategies for effective teacher development and also highlights the various pitfalls along the way (e.g., Bell, 1993; Bell & Gilbert, 1996; Briscoe, 1991; Burden, 1990; Claxton & Carr, 1991; Davis, 2002; Fensham & Corrigan, 1994; Fullan & Hargreaves, 1992; Hargreaves & Fullan, 1992; Zeichner & Tabachnick, 1991; Waring, 1979).

One of the dangers highlighted by Briscoe (1991) is that the teaching/learning situation in the classrooms may show very little change despite the professional development programmes teachers attend. This is echoed by Bell and Gilbert (1996):

... many teachers, even after attending an in-service course, for example, feel unable to use the new teaching activities, curriculum materials or content knowledge to improve the learning of their students. Unfortunately, it is common for teachers to find themselves teaching in the same way they always have, perhaps utilising some of the new materials but adapting them to fit traditional patterns. (p. 9)

The finding of a study conducted by Elmore (1995) showed that although teachers felt motivated and excited about restructuring in their schools based on constructivist views on learning, in effect they showed very few changes in their teaching practice. However, the teachers in one school in the study did show substantial change in their practice that corresponded to their espoused constructivist views. These teachers were actively involved in the formulation of the school based changes and not merely involved in carrying out the planned restructuring. Thus different forms of teacher development enable teachers to be engaged in curriculum change to a greater or lesser extent; from being mere implementers of an already designed curriculum package to

being curriculum developers themselves (see Schubert, 1986). Traditionally, New Zealand teachers have fulfilled a variety of roles in curriculum development from being curriculum change initiators or writers, conductors of teacher development, to being implementers of curriculum change.

Stenhouse (1975) expands the concept of professionalism of the teacher to include curriculum decision making and being involved in the role of ‘teacher as researcher’. An important consequence of this is the sense of control and ownership that the teacher feels he or she has over the new curriculum (see Baird, Mitchell & Northfield, 1987). This sense of empowerment is viewed by researchers as critical for effective curriculum change (Bell & Gilbert, 1996; Pedretti & Hodson, 1995). My research will explore how much the teachers in this study felt they had control over the new curriculum to be implemented.

There are other issues involved in teacher change. Implicit theories held by teachers about the nature of knowledge, of teaching and learning, greatly affect the way they teach in their classrooms (e.g., Claxton & Carr, 1991; Prawat, 1996). Because of this, the first step to bringing about any change in the classroom is for teachers to reflect on their current classroom practice and beliefs about teaching and learning (Johnson, 1992). For some teachers, their beliefs and practices may be quite in line with the change proposal, and they are merely required to make small adjustments to accommodate the curriculum change. However, for other teachers, the curriculum change may require substantial new learning and changes in their practice “...which require them to value different learning outcomes, play new teaching roles and display new teaching strategies and skills” (Johnson, 1992, p. 105). Shulman and Shulman (2004) attest to this variability in teachers undergoing change:

... we were reminded constantly of how enormously different from one another were the teachers with whom we worked, and especially how much they varied in the ease or difficulty with which these novel ideas were accepted and applied in their work. (p. 257)

My research will explore the starting points of the different teachers with respect to their beliefs and practices, and discuss the issue of the extent of pedagogical change needed for them to accommodate the teaching of the new curriculum.

Another factor that was found to be important in a number of research studies cited in Prawat (1996) is the importance of collaboration among teachers when undergoing change. They conclude from in-depth case studies of schools undergoing restructuring that the presence of an on-site colleague who can serve as a resource and sounding board is an important factor in individual teacher's success in changing practice.

Thus literature reported here highlights the importance of teacher development to enable teacher change when trying to bring about a change in curriculum. The involvement in and ownership of the curriculum change by the teachers, the role of their beliefs and existing practices, and the presence of on-site supports have also been highlighted. The central role of the teacher in curriculum change is further explored in the following section.

2.5 Central Role of Teacher in Curriculum Change

The role of the teacher in any innovation, big or small, or a change in curriculum has been described as central by many writers (e.g., Fullan, 2001; McGee, 1997; Olson, 1999).

Educational change depends on what teachers do and think – it's as simple and as complex as that. (Fullan, 2001, p. 115)

This view of researchers stems from the obvious realisation that the two main players in the classroom where the curriculum is usually enacted are the teacher and the students. The interactions between these two main players are based on teaching programmes, timetables, assessments, etc. These are at the core of the translation of any innovation or curriculum change into the classroom and are the key to the success or otherwise of the intended change.

There are other factors that come into play in these interactions which are not so obvious, such as, personality, beliefs, background, experience and expertise. These are brought into the interactions by both teacher and students. For instance, students bring in their attitudes and beliefs, backgrounds such as socio-economic status, developmental stage, ability, and various other characteristics. Similarly the teacher brings in her/his personality, attitudes and beliefs, background, experience, expertise and the curriculum expectations. This list is not exhaustive and I shall delve further

into the issues regarding the teacher's contribution to a change in the classroom in the following subsections.

2.5.1 Role of the teacher

The role of the teacher has changed over time. Teachers now need to pay greater attention to student interests and differences, act as clinicians, manage new technologies, and implement rapidly changing educational policies (Olson, 1999). Recent changes in teachers' work include heightened expectations, broader demands, increased accountability, more 'social work' responsibilities, multiple innovations and increased amounts of administrative work (Hargreaves, 1994). Thus teachers are constantly being called to change in terms of their roles. According to Fullan (1991), the implementation of a new policy will require changes in actual practice along three dimensions: the use of new or revised materials, the use of new teaching approaches, and the alteration of beliefs. The first dimension involving the use of new materials is usually the most visible change; the third dimension which involves the change to deeply held beliefs is the more difficult one to deal with. The following section will look into the complex area of teacher beliefs.

2.5.2 Teacher beliefs

Rokeach (1968) defines a belief as any simple proposition which may be conscious or unconscious and can be inferred from what a person says or does. He argues that the belief system has central and peripheral parts where the more central the beliefs, the more important they are and more resistant to change; but if they do undergo change then there is a greater impact on other beliefs. He introduced the concept of 'disbelief systems' where together with beliefs they form configurations of belief systems rather than a simple linear dimension.

Bruner (1983) expressed three generalisations about opinions, which can also cover beliefs. Firstly, they provide hypotheses for filtering and organising news and knowledge. Secondly, they are projection screens for inner fears and needs. Thirdly, they provide a means of aligning oneself with others who share similar views and values. This is a useful way of thinking about beliefs, namely, as the effect of the

individual's past experiences, which gave rise to the beliefs, on the shaping of new experiences.

The role of beliefs held by teachers when dealing with an educational change has been explored by several writers. Zuga (1992) states that teachers' beliefs about education and students cause them to select and organise the processes that need to be taught in a variety of ways giving rise to differences in the curriculum orientations between teachers. Clark and Peterson (1986) discussed the implicit theories of teaching and learning held by teachers. Partially articulated theories, beliefs, and values about the teacher's role and about the dynamics of teaching and learning form the frames of reference through which individual teachers perceive and process information. They form the psychological context within which planning and decision-making occurs: "... a teacher's cognitive and other behaviors are guided by and made sense in relation to a personally held system of beliefs, values and principles" (Clark & Peterson, 1986, p. 287). Pennell and Firestone (1996) commented that the varied responses by teachers to mandated changes reflected deeply held beliefs. Cheng (1999) found that when teachers modify practice it does not necessarily mean that their core beliefs have undergone change too, especially in the area of assessment-driven change. In the Kensington Elementary Education Project, change occurred but the beliefs systems of most of the teachers remained intact (Smith, Kleine, Prunty & Dwyer, 1986). A quote from one of their teachers exemplifies this:

... I had been brought up in a traditional school and I knew the value of drills and the value of grammar and learning in an orderly process and I was upset time and again by not seeing this orderly process. ... I believe I was innovative but I wasn't happy with that. (p. 127)

The dilemma that teachers face when their core beliefs that have been derived from past experiences are not in line with the practices that are required by the educational change is clearly seen in the above quote. McGee (1997) describes change as a highly individual experience, which affects different teachers in different ways. Bell and Gilbert (1996) highlighted the importance of knowing that the personal beliefs about oneself and others could hinder change. Examples of such beliefs are given in Claxton and Carr (1991): 'your worth depends on your success; your worth depends on your consistency and predictability; your worth depends on your clarity; your worth depends on being cool as strong feelings are immature and need to be covered up'.

They state that such beliefs can stand in the way of changing practice if they are not brought to the open and addressed.

If an innovation is small, mechanistic or simple, schools will not change or sustain any initial change, as the teachers' central beliefs do not change so readily (Smith et al., 1986). The innovation may be altered by the teachers to fit the social situation as well as to fit in with their belief systems. Schools have identities (values, norms and goals) that are the result of long periods of day-by-day interactions and activities; and individual beliefs and sentiments shape, as well are shaped by, these influences. In educational practice, actions and skills are correlated with beliefs, and teachers need to be able to take actions that exemplify their beliefs (Smith et al., 1986). The innovation thus needs to tie in with the belief system of the teachers, or there need to be attempts to change the belief system, to encompass the curriculum change.

Hativa (2000) studied two tertiary teachers who were rated poorly by their students and were subjected to an intensive intervention which included information on pedagogical knowledge. The conclusion reached by the study was that improvement in teaching is not merely brought about by changing teachers' classroom behaviours but by changing their beliefs about teaching and students, and also their personal characteristics. Thus, linked with belief systems, personality and interpersonal processes are seen as having influences on using innovative pedagogy or other educational innovations (see also Smith et al., 1986).

2.5.3 Teacher personality

The personality of the teacher linked with previous experiences and stage of career are relevant factors when looking at whether the teacher is open to change (Fullan, 1991). Teachers who are more self-actualised and have a greater sense of efficacy will be prepared to take action and persist with the effort to implement an innovation. The psychological state of a teacher may predispose them to seek improvement to a greater or lesser extent. However, there are some teachers who consider themselves experts in their subject area (e.g., Physics) and who feel no need to change; they do not consider the innovation or curriculum change an improvement (Ramsay, Harold, Hwak, Kaai, Marriott & Poskitt, 1990). Hargreaves (1994) contends that personal factors such as personal maturity, stage in life cycle, ethnicity, gender identity,

religious beliefs, ideological commitments and career goals have a bearing on how teachers relate with their colleagues, their orientation to change and the quality of their classroom instruction. These personality factors underpin the teacher's capacity for change.

2.5.4 Summary

In summary, as the teacher is central to bringing about the curriculum change, the beliefs, personality and capacity for change for each individual teacher plays a part in the success of the change. Teacher development will not have the same outcome for each teacher as their starting points, backgrounds, personality and beliefs are among the individual variations that interact with the teacher development programme and produce different outcomes for each teacher.

2.6 Interpretation of Curriculum Change by Teachers

The model of curriculum development that is used affects the role of the teacher within the change. Models can range from sequential and rigid to flexible and interactive with the teacher involvement being greater at the flexible and interactive end (McGee, 1997). The conceptions of the curriculum as being either technocratic or critical also determine the role of the teacher (McGee, 1997). The technocratic perspective separates the construction of the curriculum from policy-making and implementation and so the teachers are then usually the implementers of the change. The critical perspective of curriculum views teachers as being more active in the actual design of the curriculum. Ozga (2000) prefers to see teachers not merely as "passive receptacles of policy" (p. 7) but rather as active in policy making and for this to happen, education policy needs to be made more accessible to the teachers.

When teachers are attempting to implement a curriculum change, they will first of all need to interpret the new curriculum. The problems of interpretation of curriculum by teachers discussed by a number of writers (such as Ball & Bowe 1992; Black & Atkin, 1996; Fullan, 1991; Goodson, 1994; Shipman 1974) are more likely to happen when a technocratic, sequential and rigid model of curriculum development has been pursued. Despite a body of research that calls into question the success of such curriculum development models, these approaches are alive and well today and form

the basis of a large proportion of the reforms in many countries (see Sharp & Grace, 2004).

When a new curriculum is encouraged or mandated, the teacher has to, first of all, come to understand it and know what it is all about. Sometimes this first step is assumed to happen naturally after a glossy document has been produced and perhaps a supporting document on guidelines for implementation has been issued. At best, teacher development courses on the impending change will be organised. This is the lot of a majority of teachers, except the few who were involved in the design or planning of the curriculum change. This type of innovation has been called by many names: mandated, imposed, centralised, top-down, outside-in, and curriculum as prescription (Barrow, 1984; Fullan, 1991; Goodson 1992; Olson, 1999). The manifestation of the curriculum change in the classroom is the point at which the centrality of the teacher as the change agent becomes clear.

The change affects the teacher who then effects a change in her/his classroom. The change that is effected is not necessarily the change that was planned by the curriculum developers. Thus the functional curriculum or the operational curriculum can be different to various extents from the intended curriculum or the official curriculum (Eisner, 1994; Eraut, 1990). The different interpretations of the curriculum by teachers could be due to various factors (dealt with later in this section) but whatever the reasons behind the teacher's interpretation of the curriculum, Hargreaves (1993) hands over the ultimate responsibility for educational change and learning to the teacher:

... the teacher is the ultimate key to educational change and school improvement. ... Teachers don't merely deliver the curriculum. They develop, define it and reinterpret it too. It is what teachers think, what teachers believe and what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get. (p. viii)

Goodson (1994) also emphasised the reality that what is finally enacted in the classroom is not necessarily what was planned by the curriculum writers or developers:

... for curriculum can indeed be reinterpreted, text can be deconstructed, every prescription can be subverted, inverted, converted or perverted. (p. 13)

However, the alternative interpretations are not necessarily always deliberate. They can arise due to misunderstood aspects of the change, lack of clarity of the change, a sense of false clarity, unfamiliar curriculum content, adapting to existing practice, and resistance within accommodation. These will be discussed below.

Shipman (1974) analysed the Keele Integrated Studies project and although the study was done more than thirty years ago, this historical analysis is still useful in terms of examining current curriculum change situations. Shipman wrote that some teachers had not read or understood sections of the document relating to the principles of integration, so they defined the project in their own terms, resulting in the basic principles behind the project being usually misunderstood or unconsidered. Sometimes teachers cannot even identify the main features of the curriculum programme that they are attempting to implement (Barrow, 1984).

The lack of clarity may not be a problem that necessarily lies with the teacher because the curriculum change or document itself can be fraught with conflicting ideas. There may be unresolved tensions inside the project and the demands could be unclear or not insisted upon (Bell, Jones & Carr 1995; Shipman, 1974). The teachers will then take on their preferred meanings. In the Keele Project, content and ideas were well laid out but the pedagogical issues were neglected and so this led to much confusion. Thus alternative interpretations are possible at even the conceptual level if there is no overarching theory underlying the change project that is understood by the teachers involved (Jenkins, 1974). Fullan (1991) reiterates that many educational changes are adopted without any clear notion as to their specific meaning. Crandall, Eiseman & Louis (1986) suggest that too often innovations lack clarity about aspects of the innovation that are necessary to help users to know what to do. Thus the problem of alternative interpretations does not lie entirely on the shoulders of teachers involved in curriculum change; lack of clarity of the educational change can pose a serious issue.

There is the other problem of 'false clarity' where the change is interpreted in an oversimplified way, failing to incorporate significant features, and the teachers think they are using the new approach but actually are not (Fullan, 1991). Such alternative interpretations tend to happen also when teachers try to adapt the new ideas to pre-existing ideas and practices (McGee, 1997; Shipman, 1974). Similar to that notion is 'resistance within accommodation' (Troman, 1996) where policies developed

externally are filtered through the teacher's existing professional perspectives and accommodated therein.

The interpretation of the intended curriculum change is one of the major hurdles in the successful implementation of a curriculum change. The present research will seek out the teacher interpretations of the new physics curriculum and contrast that with the intended curriculum as planned by the curriculum writers. The next section will explore the issues surrounding successful and unsuccessful curriculum change efforts and will highlight the focus this discussion leads to.

2.7 Successful and Unsuccessful Curriculum Change

Various conditions can give rise to success or lack of success of an educational reform. There are two levels where appropriate conditions can give rise to an effective curriculum change: one is at the wider organisational level and one is at the level of the individual teacher. The connection between the two levels is that systemic curriculum change requires teachers to change; to accommodate and promote the change in their classrooms.

Reform that deals with changing the structures, such as governance and work structures, tends not to affect the deep structure of teaching and learning (Fuhrman, 1995). The deeper questions of knowledge and competence, which are at the core of changes in teaching and learning, tend to be obscured or omitted by these structural changes. Fullan (1998) talks about the three components that need to be worked together to get effective change: reculture, retime and restructure. He says that too often changes stop at the restructuring stage whereas reculturing and retiming should drive restructuring to make significant changes in learning. Reculturing involves the transformation of habits, skills and practices of educators with a professional community focus on what students are learning and the actions to be taken to improve the situation. Retiming involves more resourceful use of time for both teachers and students.

Curriculum innovation that is planned outside the school often does not get successfully adopted at the school (Barrow, 1984). Olson (1999) claims that the failure of an imposed curriculum is due to insufficient consideration for teacher

qualifications, different goals for pre- and in-service teacher training, contradictory demands of different stakeholders and controversial intended outcomes for the reform. *Science in the NZ Curriculum* has been described as having inherent tensions within it where "different parts or aspects of the curriculum are coloured by different educational and political theories and ideologies" (Bell, Jones & Carr, 1995, p. 38). Such a curriculum excludes the teacher and has mixed messages about the intended curriculum. Thus, teachers are caught in the middle when they have to design viable programmes based on the official curriculum for their classrooms.

Again, Shipman's historical analysis (1974) of the Keele Project has relevance to the present research into curriculum change. He found that the main barrier to genuine implementation was the local horizons and narrow terms of reference of the teachers. (This referred to the second level of curriculum change which involves the individual teachers.) He found that the lack of success of the project was due to the lack of involvement of the teachers in decision making and that they were reluctant to be involved in consultation. (Thus the connection between the two levels; the wider organisational change and change at the individual teachers' level, was limited.) He concluded that projects that have little personal contact between the project staff and the participating schools inhibit implementation of the innovations.

Assessment was also seen as the greatest single problem as the traditional testing methods were inappropriate for the new curriculum (Shipman, 1974). Also 'high stakes' national testing regimes (such as the senior school external exams) can restrict the exploration of a variety of pedagogies to be used in teaching the curriculum due to teachers "teaching to the test" (Madaus, 1991). This is echoed by Smith and Rottenberg (1991) whose extensive study found the significance of high stakes tests on the teaching of a subject. Teachers narrowed their focus and included only topics that were in the tests; they did not cover anything that was not in the external exams. They reported feeling that their own performance as teachers is undermined by external tests. Thus external examinations can become a nemesis to innovative teaching.

To identify the conditions for a curriculum change to be successful, it is important firstly to understand the process of change. Change is seen as a process rather than an event (Fullan, 1991; Guskey, 1986; Hargreaves, 1994). Three broad phases in an

educational change process are described by Fullan (1991). They are first, the initiation phase, second, the implementation phase, and third, the continuation phase. According to him, these phases should not be rushed and a major restructuring effort could take from five to ten years. However the life-term of a government tends to be far shorter than that and so, many efforts start with gusto at the initiation phase and become under-resourced by the time they reach the implementation phase. This is described succinctly by Fullan (1991):

Bureaucratically speaking then the political and symbolic value of initiation of change for schools is often of greater significance than the educational merit and the time and cost necessary for implementation follow through. (p. 61)

Fullan (1991) lists the important factors at the initiation phase for a successful reform as relevance, readiness, and resources. Relevance incorporates the need, clarity and utility of the change. Readiness involves the practical and conceptual capacity to use the reform. Resources encompass the accumulation and provision of support for the change. Miles (1987) emphasises the need for a clear model for proceeding with the change that characterised projects with more successful start-ups at the initiation phase. The factors listed in the implementation phase as having important impact on the success of a reform are need, clarity, complexity, quality and practicality (Fullan, 1991). Prioritising the needs, interpreting the change accurately (clarity), realising the difficulty and the extent of change required by teachers who were implementing the change (complexity), and the quality and practicality of the change within the unique teaching and learning situation in each school, are all considered important in leading to the success of the change.

Fullan's framework highlights the problems faced by the least successful of the Nuffield Biology projects which was ecology (Dowdeswell, 1962, cited in Goodson, 1987). The teachers had problems with the different teaching methodology, the basic attitude and thinking about teaching and learning which was different to theirs, the lack of time, and the organisational problems which made huge demands on them and were impractical. Change can become problematic when the work conditions do not keep pace with the proposed change.

Hargreaves (1994) goes further still and suggests that schools are out of pace with the rest of society. There is a need to look at society and the wider context to explain the

educational changes being proposed for schools; to bring the schools' curriculum in line with changes in society. He distinguishes the chasm between schools and society, especially secondary schools which are still in the grips of modernity while the post-modern society requires "more relevant and engaging student learning, more continuous and connected professional development and more flexible and inclusive decision-making" (p. 23). The lack of engaging the teachers in relevant and effective professional development and in curriculum decision making is seen as a neglect of the central role of the teacher in successful curriculum change implementation:

... the limited impact of curriculum innovation on classroom practice have pointed to the reformer's neglect of the central role of teachers' intentions and pedagogical expertise in effecting significant classroom change. (Butt, Raymond, McCue, Yamagashi, 1992, p. 53)

This is echoed in various ways by many other researchers and writers (Atkin 1998; Gamoran, 1997; McGee, 1997; Olson 1999).

In summary, this section highlighted the importance of connections between the two levels involved in curriculum change which are the wider organisational level and the level of the individual teacher. The dangers of focusing on the structural aspect of the new curriculum and not dealing with the deeper issues of teachers undergoing change were discussed.

When faced with an educational innovation, teachers are, more often than not, required to change at least in their practice if not in their beliefs. The next section will look at the factors that support teachers to change as well as those that hinder the change.

2.8 Factors that Support or Hinder Teacher Change

A number of researchers including Doyle and Ponder (1977), Fullan (1991), Jones (1999), Lee (2000), McGee (1997), and Waugh and Punch (1987), have studied teachers undergoing change and each has come up with a list of criteria for a successful shift in practice. These are listed in turn and then a synthesised criteria list is developed.

2.8.1 Background for the synthesised list of criteria for change

Fullan (1991) in exploring the meaning of educational change has listed four main criteria why teachers change:

1. Need/evidence: Does the change address a need? Will students be interested? Will they learn? Does the change work, that is, produce the claimed results?
2. Procedural clarity: How clear is the change? What will teachers have to do?
3. Personal costs and benefits: How will it affect the teacher personally in terms of time, energy, new skill, sense of excitement, competence, and interference with existing priorities?
4. Peers: How rewarding is being involved in the change in terms of interaction with peers or others?

The first three factors corresponded to Doyle and Ponders' (1977) notion of teachers' practicality ethic of congruence, instrumentality, and cost. How congruent was the change with respect to the needs of the teachers? How instrumental was the change with respect to what the teachers need to do? Finally how is the change going to cost the teacher with respect to their time, energy and psychological welfare? In answering these questions, teachers' practicality ethic is seen as an indicator of whether teachers will be willing to proceed with the change.

The above factors can also be compared with Waugh and Punch's (1987) model of teacher receptivity to system-wide change. These are:

1. Beliefs on general issues of education;
2. Overall feelings and attitude toward the previous educational system;
3. Alleviation of fears and uncertainty associated with the change;
4. Practicality of the new educational system in the classroom;
5. Perceived expectations and beliefs about some important aspects of the new educational system in comparison with the previous one;
6. Perceived support for teacher roles at school in respect of the main referents of the new educational system;
7. Personal cost-appraisal of the change.

The comparison shows that there is considerable overlap in terms of teachers' needs and cost/benefit analysis of the change situation; however, the main difference in emphasis in the models is the role of teacher beliefs which is emphasised in Waugh and Punch's model.

Lee (2000) did a study in Hong Kong using Waugh and Punch's model. His results showed some alignment with the model such as perceived non-monetary cost benefit, perceived practicality of the guidelines, perceived support within and outside school, and issues of concern. He also came up with some other factors that were important for the teachers he studied. The additions to his list were procedural clarity and planning (see Fullan's list above), timing and scale of the programmes, distribution of workload, and the appointment of a coordinator.

Jones (1999) summarised some factors that the researchers found in their study of teachers attempting to change their own concepts of technology and technology education in New Zealand. The following factors were seen as having a large impact on how willing teachers were to change: perceived need for change, background experience, subject subcultures, level of support given to teachers during any change process, and personal disposition toward dealing with implications of these changes (p. 168).

McGee in his book exploring teachers and curriculum decision-making (1997, p. 229) provides a list of premises for teachers to change:

1. Teachers decide on own priorities for change;
2. Target whole staff in a school;
3. Teachers 'own' the change process;
4. Change centered on school needs;
5. Outside agent facilitates change;
6. A clear sense of direction and vision agreed on by teachers.

Distilling the common threads running through these studies, I have identified seven factors which appeared influential in enabling teachers to change. These factors recur in the lists given by the various researchers, though some may be expressed in other ways. They are seen as important and critical considerations for teachers undergoing change:

1. Need for change;
2. Beliefs about educational issues and the change;
3. Clarity of the change;
4. Practicality of the change in the school and the community;
5. Supports during the change;
6. Personal costs to the teacher and the possible benefits;
7. Personal disposition toward change.

Each of these factors is described in more depth in the subsections that follow. These factors are expanded and justified with views from other writers that support them.

2.8.2 Synthesised list of criteria for teacher change

Need for change

Change will be sought or looked at favourably if teachers feel a need for change. They could be dissatisfied with what is happening at school or in their classrooms and feel a need for change. One main resistance to change is when the present program is working well and teachers feel no need to change (Shipman, 1974). When a new initiative is to be implemented, teachers can view it as something that they are already doing and adapt it into their existing practice without much change; they just appear to change (McGee, 1997). Hargreaves (1994) describes the desire to change practice and the desire to conserve practice that teachers already value as not being mutually exclusive depending on the conditions of the change.

Beliefs about educational issues and the change

Teachers' beliefs with respect to educational issues about teaching, learning and their subject, are like filters through which they make sense of the proposed change. These beliefs form frames of reference through which individual teachers perceive and accommodate the change (Clark & Peterson, 1986). This is an aspect of their professional judgement that is influential in how they accommodate the proposed change.

The identity of the teacher especially as a subject specialist is defined with its inherent set of beliefs about the subject and the goals in teaching and learning. This can be challenged by an incoming curriculum change (see Goodson, 1987).

Clarity of the change

Teachers need to be clear about what the change is about. Too often, teachers are expected to implement changes without any clear understanding of what the changes entail and the purposes behind them. Those affected by change may end up being "unclear about its origins or purpose; and its relevance to them" (Hargreaves, 1994, p. 23).

Practicality of the change in the school and the community

The change needs to be able to be accommodated, or at least be adaptable, within the school structures such as timetable, assessment modes, and available resources. Also, students' ability and attitudes, views of the wider school community such as parents and employers, and the available time and energy resources of the teachers need to be taken into account:

At the heart of change for most teachers is the issue of whether it is practical. ... complex and potent combinations of purpose, person, politics and workplace constraints ... through these ingredients teachers' own desires for change are either constructed or constrained. (Hargreaves, 1994, p. 12)

Supports during the change

Supports in the form of appropriate teacher development and/or on-going collaboration among colleagues and facilitators or coordinators during the implementation of the change are seen as helpful for teachers. Collaboration is emphasised by Olson (2002) who views the development of the professional self of a teacher occurring in a community of persons involved in teaching, as such collaboration is seen as an integral part of the process of reform. Such supports can contribute to the overcoming of teacher isolation discussed by a number of researchers (Ahlstrand, 1994; Hargreaves, 1994; Huberman & Miles, 1984; Lortie, 1975). Need for supports has also been identified as important for teachers attempting change (Fernandez, 1994; Fullan, 1991; Hargreaves, 1994; McGee, 1997).

Having an outside facilitator, consultant, coordinator, or supervisor has been found to be helpful for teachers attempting change because such people can be good leaders or sounding board; they can help with resources and ideas; and they can ensure greater collaboration with respect to the change (Lee, 2000; Olson, James & Lang, 1999). Fullan (1999) sees collaboration, both within the school and outside the school in the form of links with the wider community, as supportive for change to be successful.

Personal costs to the teacher and the possible benefits

The personal costs to the teacher when trying something new include fears, risks, uncertainties, and the possibility of failure. The teacher may be reduced from being an expert on the subject to a novice because of the change. Spillane (1999) suggests that as a consequence, teachers need secure spaces to radically alter their practice. The need for teachers to experience the effects of teaching a new curriculum or using an innovation, to see in particular the effects on student participation and learning, is highlighted by Guskey (1986). He states that teachers' experiences of positive outcomes for students will precede any changes in their beliefs or attitudes about the innovation.

Other personal costs involve the amount of time and energy required to be expended in implementing the change. However, personal costs can be overcome with support and an understanding of the change process (Bell & Gilbert, 1996; Claxton, 1989). This leads to personal benefits that could include opportunities for promotion, improvement, success, or just the excitement of learning something new.

Personal disposition toward change

Personal disposition includes the teacher's personality, their background experiences, their career stage, and these will impact on the psychological state of the teacher. The psychological state will dispose the teacher towards a greater or lesser capacity for change. When teachers have been asked to talk about their work, many of them brought in aspects of their life outside the classroom; thus wider life issues impinge on the teacher's disposition to their work and change (Hargreaves, 1994). Background experiences of teachers give rise to beliefs that are quite resilient to change despite the good efforts at teacher training (Goodson, 1992). However Bell and Gilbert (1996) have argued that providing support for the personal development of teachers within

teacher development programmes can have a positive effect on teachers' disposition to change.

The above factors seem especially applicable when the educational change is initiated from outside the school (termed "outside-in" by Fullan, 1999), top-down, or mandated. They incorporate and distill some of the literature that has been written about teachers undergoing change. This area is indeed very wide and important given the central role of the teacher in any educational change, big or small.

This list of factors has been useful for deciding which areas to explore during the interviews with the teachers in this research. The list of factors is also used in Chapter 9 of this report to organise the emergent issues from the interview data about the conditions that enabled or disabled teachers taking on board the curriculum change studied in this research.

2.9 Other issues: Teacher Involvement

There has been a trend in some curriculum change projects to move away from top-down, outside-in forms of educational change, and a move towards involving the teachers in the curriculum development process. McGee (1997) laid out three levels in which teachers participate in the curriculum development process: national level (usually very few do that; in writing new syllabus and curriculum statements), school level (revising school programmes in a subject or a department's course) and classroom level (developing programmes for the teacher's own class or classes). Teachers traditionally have been mere implementers of pre-designed curricula or innovations. However, there is a history of startling lack of success of such changes, and a suggestion is to involve teachers and to use their knowledge of their students and classrooms to better design curricula that have a chance of being implemented successfully.

On the other hand, Barrow (1984) questions how well equipped teachers are to design curricula. How much preparation do teachers receive to incorporate that as part of their job specification? The question appears quite valid given the narrow focus of the many teachers in the classroom. There are similar calls from many quarters (Atkin, 1998; Barrow, 1984; Carr, McGee, Jones, McKinley, Bell, Barr & Simpson 2000;

Goodson, 1992; Hargreaves, 1994; McGee, 1997; Olson, 1999; Shipman, 1974; Snook, 1998) for teachers to be better informed, have a wider perspective, to know the makings of a curriculum, to know the basis for what they are teaching, and to realise the ideologies, conflicting or otherwise, that underlie a new curriculum: the interplay of political, economic, academic, educational and social forces within an innocuous looking curriculum package. There is probably now a dawning of the era of the “teachers’ voice” (Goodson, 1992) in which teachers' perspectives and perceptions are taken more seriously (Hargreaves, 1994).

There is also a move toward building the capacity to change: teachers as learning entities themselves, learning and changing (Fullan 1993, 1999; Hargreaves, 1994; Senge, 1992, 2000). This necessitates a change in the psychology of teachers so that they view teaching as a dynamic activity, always in flux, always changing. The job description of teachers perhaps should include 'having the ability/capacity to try out and take on new ideas'. However, it is not helpful to have unthinking practitioners jumping on the latest bandwagon. There is a need for reflective and critical thinking teachers keeping in mind the core purpose of teaching which is enhancing student learning. Ideas such as ‘technocratic-reductionist’ (teacher as skilled technician) versus ‘professional-contextualist’ (teacher as reflective practitioner) are contrasting conceptions of teaching (Locke, 2001) which may be useful in delineating the role of the teacher within a curriculum project.

This section highlighted the potential of greater involvement of teachers in curriculum change where they are not merely receivers of already designed curriculum but active architects of the curriculum. Such involvement holds the potential of developing a curriculum that is meaningful to the teachers and thus enhances the possibilities for successful implementation. The pros and cons of this is that teacher knowledge of their students and classrooms can lead to a more successful design of curriculum; however, pitched against that is a teacher’s narrow focus on teaching that will not address the wider issues of curriculum. The latter limitation is not inevitable and the possibility of widening the perspective of teachers to include the more salient features of a curriculum is supported by many researchers (e.g., Ozga, 2000).

2.10 Towards an Understanding of Pedagogical Change

The categories or factors listed in section 2.8 are fundamentally descriptive and though illuminative of the situations when a change may occur, they provide limited insights into the dynamics of change. These descriptive categories need to be augmented by categories related to theories of the dynamics, or process, of change. A sociocultural perspective can provide insights into the process of pedagogical change and give an account of the essential nature of such change (see Chapter 3). At this level of explanation, a proposed change in pedagogy is seen to demand a cultural shift relating to what it means to be a teacher of physics and, indeed, involving a “renegotiation and reconstruction of what it means to be a teacher ...” (Bell & Gilbert, 1996, p. 13).

Conceptions about the nature of science, about the goals and purposes of teaching physics, and about the teaching and learning of physics are identified by Fischler (1994) as important factors that impact on the thinking and acting of physics teachers. If these conceptions are at variance with the views in the proposed innovation or change, teachers will be "constructing, evaluating and accepting or rejecting for (themselves) the new socially constructed knowledge about what it means to be a teacher (of science) and managing the feelings associated with changing their activities and beliefs about science education ..." (Bell and Gilbert, 1996, p. 13).

The usual practice with regards to the dissemination of a new curriculum is to have professional development for the teachers involved. It is important, however, to consider the nature of that professional development provided. Does the professional development enable teachers to grapple with issues given above in relation to the new curriculum?

Bell and Gilbert (1996) suggest that professional development needs to go beyond the technical aspects of the change and develop understanding of the underlying ideas:

Professional development ... involves not only the use of different teaching activities but also the development of the beliefs and conceptions underlying the activities. (Bell and Gilbert, 1996, p. 13)

The process of curriculum development, the theories that underlie the change, the arguments that are involved in the production of a new curriculum, all need to be exposed to the teachers so that they are empowered to make informed decisions about the change. They also need to be able to understand why the impetus for change has come about. Understanding the underlying theories or ideas behind the change is the first step in confronting their own ideas and working towards a change, or reconciliation of the two if divergent, or even a rejection of the new ideas if found unacceptable.

2.11 Summary

In summary, many conceptions of curriculum were explored in this chapter and the meaning most closely linked to this research was that of a curriculum that is built on particular social, historical, cultural, and political values as well as subject discipline traditions of society. This view was built into *The National Curriculum Framework* and into *Physics in the New Zealand Curriculum* (see Chapter 1). The values and traditions were distilled into the curriculum documents and underpinned much of what was written in them with injunctions about purposes, pedagogy and content.

For countries with a national curriculum, changes in society impinge on the national guidelines for curricula and this will affect the school curriculum. Thus change in school curriculum is seen as an inevitable process which can happen in a number of ways. Top-down changes are usually generated outside the school, usually within the Ministry of Education, and then introduced to the schools through facilitators and teachers. Diametrically opposed to this would be curriculum changes that are developed from within the grassroots level of the practitioners and then official status sought for the changes.

The curriculum changes in New Zealand in the 1990s were generally top-down with some degree of consultation with practitioners and other stakeholders. The curriculum change for physics at secondary schools was carried out roughly in two stages: one, the development of *Physics in the New Zealand Curriculum* and the other was the implementation of this document in secondary schools.

The view highlighted in this chapter that teachers are central to any curriculum change led to the unpacking of the needs of teachers to enable them to change effectively. A list of seven criteria was synthesised here from the writings of other researchers as the essential elements to consider when teachers are attempting a change in their teaching. These seven criteria were used to illuminate the experiences of the teachers interviewed in this study, and formed the superordinate categories to organise the emergent ideas that arose from the interview data with the teachers regarding their difficulties about implementing the curriculum change.

In Chapter 3, the theoretical underpinning of this research, that is, a sociocultural theoretical perspective, is explicated and the discussion focused on a particular analytical framework designed by Wenger (1998) which was used as a lens in studying the data of this research. The important role of the 'artifact' in sociocultural theory and in this research is also considered in depth. Chapter 3 will also draw out the Research Questions of this thesis.

Chapter 3 ➤ Literature Review of Sociocultural Theoretical Perspectives

3.1 Introduction

My research is about curriculum change and an integral aspect of this is teacher change. For any teacher change to occur there needs to be learning. When a new curriculum is designed, teachers need to learn what it is all about before they can integrate any change into their teaching. How people learn has been the focus of research for many years and the theories that have been put forth have undergone substantial changes over time, especially with the movement from behaviourist to more cognitive theories of learning.

Two major cognitive conceptions of learning can be contrasted, each with its own metaphor (Salomon & Perkins, 1998). One conception sees learning as an individual activity where the acquisition of knowledge and cognitive skills are transferable commodities. In this conception, knowledge and skills are entities that exist outside the individual and can be transferred and acquired by the individual (e.g., Anderson, 2000). The other conception views learning as a sociocultural activity where there is collective participation of people in the construction of knowledge. Sfard (1998) echoes this distinction in delineating the 'acquisition metaphor' in which learning is an individual activity from the 'participation metaphor' in which learning is more a collective activity. However, she emphasises the need for both metaphors to give a more complete picture of learning and points to the pitfalls of being totally devoted to a particular metaphor of learning. Salomon and Perkins (1998) also acknowledge that individual or psychological aspects of learning interact with the more social aspects of learning. Thus, they suggest that “these interactions occur, to a large extent, among an individual, his or her social surroundings, and the artifacts culture provides” (Salomon & Perkins, 1998, p. 2).

Sociocultural theories of learning are useful when viewing the wide field of curriculum change. The interactions of the individual, their social surroundings and community, and the artifacts that promote or inhibit the change are key aspects of this

theory. The basic premise of sociocultural theories is that learning occurs in a social setting and is mediated by cultural objects. Sociocultural theories have been frequently used to analyse learning (Cole & Engestrom, 1993; Lave, 1991; Lave & Wenger, 1991; Rogoff, 1995; Wertsch, 1991). According to Salomon and Perkins (1998), sociocultural accounts of learning are not new but due to what was seen as a lack of theoretical rigour, they were relegated to the background by many of those studying ‘learning’ in the past. Thus the dominant focus of western psychologists of the 20th century tended to be on individual learning and the individual mind. This has slowly changed with an escalating interest in the sociocultural psychology of Lev Vygotsky during the last two decades of the 20th century. His ideas have been extended in many directions and have proved valuable in understanding socially and culturally situated processes of learning (Lave & Wenger, 1991).

In my research, the document *Physics in the New Zealand Curriculum* was central to the curriculum change that was initiated for physics at secondary schools in New Zealand. The writing of the curriculum document and the subsequent implementation of it at schools are seen as socially and culturally situated processes in this thesis. Thus in terms of sociocultural theory, the curriculum document was a cultural object, an artifact, which mediated the interactions that gave rise to a curriculum change. Given the critical role played by the curriculum document in the physics curriculum change, its theoretical basis as a cultural artifact is explored in the following section.

3.2 The Role of Artifact in Sociocultural Theory

The fundamental themes in sociocultural research deriving from the writings of Vygotsky and his followers include ideas about human action and mediated learning:

The goal of a sociocultural approach is to explicate the relationships between human action, on the one hand, and the cultural, institutional, and historical situations in which this action occurs, on the other. (Wertsch, Del Rio & Alvarez, 1995, p. 11)

However, sociocultural theorists view humans as not having direct access to the empirical world. They require the use of artifacts or cultural tools to interact with the world in obtaining information about it as well as acting on it. Artifacts are seen to “provide the link or bridge between the concrete actions carried out by individuals and

groups, on the one hand, and cultural, institutional, and historical settings, on the other” (Wertsch et al., 1995, p. 21).¹

Lantolf (2000) describes cultural tools as being either symbolic (psychological) such as language, or physical such as a document. Both are artifacts created by human cultures over time that can be handed down to succeeding generations. Each generation can modify the artifacts to meet the needs of its communities and individuals before passing them on. Thus a curriculum document can be revised, rewritten and be in a state of dynamic change to keep up with the changing needs of society.

The passing down of an artifact can be described in terms of three stages which individuals move through in the learning process. Lantolf (2000) describes the learning stages as firstly being controlled by the objects or artifacts in the learners' environment, then controlled by others in this environment, and finally learners gain control over their social and cognitive activities. These stages are referred to in sociocultural theory as object-, other-, and self-regulation. This has relevance to curriculum researchers in that these stages can be mapped onto the developments in the ways that teachers interact with a new curriculum document.

Wertsch et al. (1995) suggest that when new cultural tools are brought in, they are seen to overcome the limitations of earlier mediated perspectives. However, they suggest that each new cultural tool also introduces its own new limitations. They caution that “while the cultural tools or artifacts involved in mediation certainly play an essential role in *shaping* action, they do not *determine* or *cause* action in some kind of static, mechanistic way. Indeed, in and of themselves, such cultural tools are powerless to do anything. They can have their impact only when individuals use them” (Wertsch et al., 1995, p. 22). The cultural tools only possess the potential to shape action but their unique usage is up to the individuals using them. This is akin to the contention of Wenger (1998) that practice (or human action) is not a result of the design or artifact but a response to it.

¹ The terms 'mediational means' or 'cultural tools (or objects)' can be used interchangeably with the term 'artifact'.

The development of the cultural object, *Physics in the New Zealand Curriculum*, was part of the national school curriculum change initiatives in response to perceived changing needs of New Zealand society. It was also an opportunity to address the limitations of the earlier physics curriculum. However as Wertsch et al. (1995) caution, new limitations can arise from the revised curriculum and in terms of a common New Zealand phrase “the proof of the pudding is in the eating”, that is, the way teachers accommodate and utilise the ideas in the new curriculum document shapes the actual new physics curriculum delivered at schools.

Mediational means or cultural tools need not be supportive of genuine learning in a sociocultural context, according to Wertsch et al. (1995.) They state that the cultural tools may be selected, dictated, or driven by covert sociocultural forces and the benefits for learning may be just accidental. Thus, there may be issues of power related to the selection and support of certain cultural artifacts; as exemplified in the bourgeoisie defining what comprises elite cultural forms (Bourdieu, 1986). In terms of a curriculum document, there may be agendas from different stakeholders other than the obvious agenda of improving learning, and this can lead to conflicting themes within a document with the potential to lead to much confusion and unpredictable results.

An important acknowledgement in this discussion of the many facets of the artifact is that an artifact can leave out of consciousness as much as it brings into awareness. Lantolf (1998) points to an example of this in the case of the alphabetic system. While the alphabet affords a structure for specific aspects of language (e.g., for English, the phonemic structure of an individual word), it can hide as much as it makes apparent (e.g., for English, the effect of the sound patterns of preceding words on the actual sounds of subsequent words is not encoded by the English alphabet). Wenger provides a metaphor to describe this: the artifact is just the tip of the iceberg (see Figure 1); many of its meanings are submerged and not obvious to the uninitiated:

What is important about all these objects is that they are only the tip of an iceberg, which indicates larger contexts of significance realised in human practices. ... they are reflections of these practices, tokens of vast expanses of human meanings. (Wenger, 1998, p. 61)

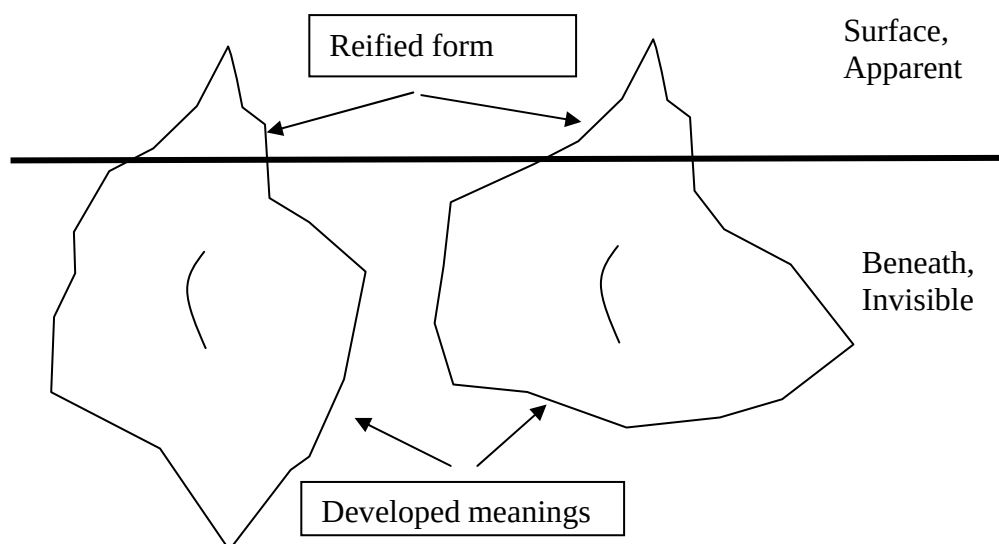


Figure 1: Application of Wenger's iceberg analogy showing two icebergs with same surface features but differing shapes under water.

This point made by Wenger is pivotal to this thesis. *Physics in the New Zealand Curriculum* seeks to encapsulate the entire senior school physics curriculum; it seeks to set out purposes, pedagogy and content for physics teachers. The words on paper form the “tip of the iceberg”; they are merely reflections of what is being proposed and much of the “vast expanses of human meanings” can remain hidden. Debates and issues underpinning the sentences in the final curriculum document are obscured to the reader.

As well as examining human action, sociocultural studies can extend to changing the cultural, institutional, and historical settings in which behaviour occurs (Wertsch et al., 1995). Human action is mediated by artifacts passed down over time, and so introducing reflexivity to this mediation is essential for cultural or organisational shifts. Thus this research explored the writing of an artifact which was based on social, cultural and historical aspects of physics education in New Zealand. It studied the interactions with this artifact by teachers whose responses can then create a new environment in which physics education at schools occur. Teacher reflexivity to their interactions with the curriculum artifact can give rise to new normative practices.

Several researchers have suggested ways in which sociocultural frameworks can incorporate ideas about change (e.g., Rogoff, 1995; McNaughton, 2002). However, this thesis will focus on the framework of Wenger (1998) as it is found to best express the processes that have occurred in the situation of curriculum change studied in this

research. Physics teachers form a community of practice; this idea and other ideas in Wenger's theory are described in more detail in the following section.

3.3 Wenger's Sociocultural Theory of Learning: Participation and Reification within a Community of Practice

The concept of a community of practice was first set out by Lave and Wenger (1991) and was further developed by Wenger (1998). Lave and Wenger (1991, p. 98) state:

A community of practice is a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice. A community of practice is an intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage.

Thus the physics teachers in New Zealand form a community of practice as they have a shared heritage of their subject discipline. They may not be in physical contact often but are connected through their common experiences and activities in teaching senior school physics. They are also part of the wider school community and perform other functions within the school. As a community of practice, they needed to make sense of the new physics curriculum document and align their interpretations and responses to the new curriculum. The curriculum writers were also from the community of practice of physics teachers but they formed a subset within that as they were three progressive physics educators who were chosen to write the new physics curriculum.

Additionally, Wenger (1998) theorised that engagement in social practice is the fundamental process by which we learn and how we become who we are. Wenger's primary unit of analysis is the informal 'community of practice' that people form as they pursue shared enterprises over time. Wenger suggests that given the right conditions, a community of practice can become a learning community. An individual can be part of several different communities of practice in their sphere of participation, playing core or peripheral roles within each one. Thus in this curriculum change situation, the writers had the core roles within the community of practice being the designers of the curriculum but were peripheral to the implementation of the curriculum, whereas the teachers played peripheral roles in the design of the new curriculum but were core players in putting the curriculum into practice in their schools. In both situations, the key feature was the learning that occurred when designing or incorporating the change.

Wenger (1998) introduced two pivotal concepts: 'participation' and 'reification'. He defines participation as “the social experience of living in the world in terms of membership in social communities and active involvement in social enterprise” (p. 55). It is both personal and social; a complex process that incorporates doing, talking, thinking, feeling and belonging as it involves the whole person. Participation is seen by Wenger as a source of a person's identity. The dynamic interplay of participation and reification is described below and represented in simplified form in Figure 2 (Wenger, 1998, p. 63 provides a more detailed figure).

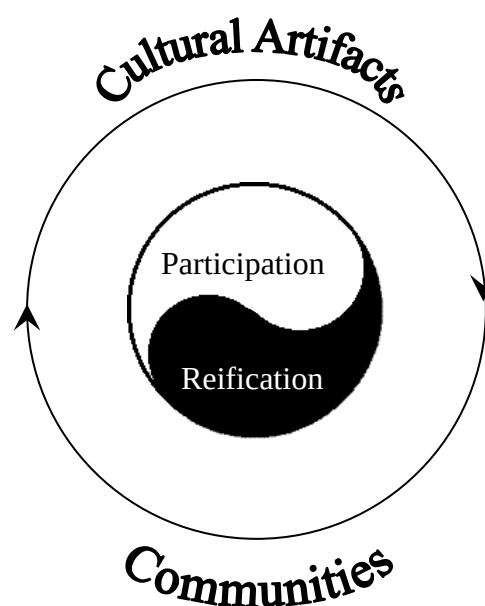


Figure 2: Simplified illustration of Wenger's model of how meaning emerges from the interplay between reification and participation

The objectification of practice that occurs within a community can be linked to the creation of artifacts as described in other sociocultural theories:

Any community of practice produces abstractions, tools, symbols, stories, terms, and concepts that reify something of that practice in a congealed form. ... aspects of human experience and practice are congealed into fixed forms and given the status of object. (Wenger, 1998, p. 59)

Reification is the term that Wenger uses to refer to this process and he defines it as:

... the process of giving form to our experience by producing objects that congeal this experience to "thingness". In doing so we create points of focus around which the negotiation of meaning becomes organized. (p. 58)²

The members of a community interact utilising cultural artifacts including objects, descriptions, signs or symbols and in doing so derive their own socially mediated personal meanings. In a community of practice, members will engage in processes such as arguing their points of view, translating what is objectified into action, and using a procedure or tool in their practice.

The two pivotal concepts of participation and reification are very apparent in the curriculum change situation that is being researched here. Their role in the analysis of the data will become clear in Chapter 10. Suffice to say at present that the writers participated in the enterprise of designing a new physics curriculum and they produced a reification of what physics education should be in New Zealand schools in the form of *Physics in the New Zealand Curriculum*. The teachers too participated in the enterprise of a curriculum change by interacting with the document (the reification) and making decisions about its implementation.

The notion of reification is seen by Wenger to be central to every practice. For him, reification covers a wide range of processes such as making, designing, representing, naming, encoding, and describing (as well as perceiving, interpreting, using, reusing, decoding, and recasting³). The following example is used by Wenger to illustrate the concept:

... if an organisation displays a statement of values in its lobby, it has created a reification of something that does or should pervade the organisation. Though this 'something' is probably much more diffuse and intangible in practice, it gains a new concreteness once framed in the lobby. It becomes something people can point to, refer to, strive for, appeal to, and use or misuse in arguments. Yet, as a reification, it may seem disconnected, frozen into a text that does not capture the richness of lived experience and that can be appropriated in misleading ways. (Wenger, 1998, p. 61)

² Wenger's sociocultural concept of reification is distinct from some of the early sociological notions. For Wenger, reification is the "thingness" yin associated with the yang of participation with the interaction resulting in the making and refining of meaning. In contrast, in the sociological notions of Marx (1894), and Berger and Luckmann (1966), the product of reification is mystification and alienation.

³ The first six processes mentioned are most closely related to the congealing of practice into fixed forms. The latter bracketed six processes are most closely related to the interactions with these forms.

In educational organisations, the development and implementation of subject curricula such as *Physics in the New Zealand Curriculum* show many of the pervasive properties of reification - they are a tangible manifestation of theorising, prone to contestation, reinterpretation and politicisation.

Wenger goes to great lengths to explain the duality of participation and reification:

Participation and reification both require and enable each other. On the one hand it takes participation to produce, interpret, and use reification; so there is no reification without participation. On the other hand, our participation requires interaction and thus generates short-cuts to coordinated meanings that reflect our enterprises and our takes on the world; so there is no participation without reification. (Wenger, 1998, p. 66)

Thus Wenger sees reification as both dependent on and facilitative of communication between participants:

... reification always rests on participation ... (it) assumes a history of participation as a context for its interpretation. In turn, participation always organises itself around reification because it always involves artifacts, words, and concepts that allow it to proceed. To be understood meaningfully as a representation of a piece of physics knowledge, an abstract reification like $E=mc^2$ does not obviate a close connection to the physics community but, on the contrary, requires it. (Wenger, 1998, p. 67)

The interaction of the two aspects, reification and participation, is seen as a process for the “negotiation of meaning” which is described by Wenger (1998, p. 53) as an “active process for producing meaning, dynamic and historical”. It incorporates many factors and perspectives and can give rise to new connections of these factors and perspectives. “Negotiated meaning is at once both historical and dynamic, contextual and unique. ... negotiating meaning entails both interpretation and action” (Wenger, 1998, p. 54). This concept of negotiation of meaning is seen at play when the writers interpret the social, cultural and historical aspects of physics education and act by writing up their meanings for the subject of physics at school. Negotiation of meaning is also a useful concept to describe when teachers have to contend with the curriculum artifact, interpreting it and acting upon their interpretations when making decisions about the curriculum implementation.

A further idea in Wenger’s theory is that there are multiple communities of practice and there are connections between these communities. In order for communities to

align their meanings and gain mutuality of understanding, it is important that continuities across boundaries be established. Wenger's theory includes two concepts important in the development of such continuities. "Boundary objects" (p. 105) are reifications around which disparate communities of practice can organise their interconnections (e.g., a curriculum document allows school auditors and teachers to coordinate their participation and communications.) "Brokering" (p. 105) refers to the connections provided by persons who can participate in more than one community of practice and thereby introduce elements of one community of practice into another (e.g., a teacher-researcher can be influential in terms of helping their teacher colleagues towards a deeper understanding of what education researchers consider to be valid methods of measuring learning gains.)

Another concept introduced by Wenger is "economy of meaning" (p. 199) in which "different meanings are produced at different locations and compete for the definition of certain events, actions, or artifacts" and it "suggests that some meanings do achieve special status" (e.g., in New Zealand, the Treaty of Waitangi artifact is associated with different meanings by the Pakeha and Maori inhabitants. During New Zealand's colonial past, the dominant meanings of the Treaty that prevailed in Government discourse were those of the Pakeha inhabitants. However, contemporary Government discourse on the Treaty has seen a renegotiation of meaning with Maori interpretations becoming more recognised). The concepts of 'boundary objects', 'brokering' and 'economy of meaning' will be used in the research analysis in Chapter 10.

As demonstrated in the discussion above, Wenger's is a comprehensive theory of sociocultural learning that looks at reification and social participation both within communities, and also between communities. Because of the complex nature of curriculum development, which involves engagement of a number of different communities of practice, there is utility in such a theoretical framework. The framework will be used later in this thesis to analyse the introduction of a new physics curriculum into New Zealand secondary schools.

3.4 Research Areas and the Research Questions

This research explores the development and implementation of *Physics in the New Zealand Curriculum* using Wenger's sociocultural framework as a theoretical basis. The key ideas discussed in Chapters 2 and 3 lead to the exploration of these ideas in three main areas: the development of the curriculum document, the implementation of the curriculum document, and the curriculum change. The particular aspects to be explored under each heading are given below.

The development of the curriculum document:

This involved exploring the process of writing and review; the influences on the written document; the issues and debates about the contents of the document; and the main changes indicated in the new physics curriculum.

The implementation of the physics curriculum document:

This involved exploring teachers' interpretations of the curriculum document; their perceptions of the changes from the previous curriculum; the professional development teachers undertook; how they implemented the new curriculum; any change in teachers' practices in the physics classroom; and the supports and barriers to the implementation of the new curriculum.

The curriculum change:

This involved exploring the usefulness of a sociocultural perspective in theorising about curriculum change; the model of curriculum change derived; and implications of the model that can enable a more effective curriculum change.

The **research questions** used to explore these areas to be studied are framed broadly as follows:

1. Viewing the curriculum as a cultural artifact, how was the new physics curriculum developed? What were the issues considered? What were the influences?

These questions are discussed in Chapters 5 and 6.

2. What were the teachers' interpretations of the document? How did they interact with the curriculum document and arrive at these interpretations?

These questions are discussed in Chapters 7 and 8.

3. What were the factors that enabled or hindered implementation of the new curriculum? What key factors can be identified from this study as being critical for successful implementation of a new curriculum?

These questions are discussed in Chapter 9.

4. Can a sociocultural perspective be used to analyse and provide insight into a situation of mandated curriculum change?

This question is discussed in Chapter 10.

5. What are the implications of a sociocultural model of curriculum change for future attempts at curriculum reform?

This question is discussed in Chapter 11.

The exploration based around these research questions could provide useful insights into the processes involved in a mandated curriculum change and enable people involved in curriculum development to bring about more effective curriculum implementation. The next chapter, Chapter 4, will deal with the methodology chosen to conduct this research based on the research questions.

Chapter 4 ► Research Methodology

4.1 Introduction

In this chapter, the basis and background for the research design chosen for this study will be argued. The area to be studied within the educational changes that were occurring in New Zealand in the 1990s was clearly defined by the researcher. A nationwide curriculum change was in progress and the researcher, coming from the background of a physics teacher as well as a researcher into mathematics and science education, decided to explore the wide area of curriculum development and implementation within the field of senior secondary physics education in New Zealand. In particular, the focus of the research is the development and implementation of *Physics in the New Zealand Curriculum*.

Having reviewed research methods in education, there were many ways open to the researcher of exploring this dynamic field. With a desire to study this field in a personal and intimate manner so as to uncover deep issues regarding change, qualitative methodology was chosen. Nationwide curriculum change processes have been studied by many researchers focusing on curriculum subject areas besides physics, as well as the political and societal influences underpinning the changes. However researchers such as Carlgren (1995), Goodson (1992), Fullan (1991), Hargreaves (1994) and Kennedy (1986) have suggested that there is a need to explore the voices of the people within an educational change experience; for example, "... a research mode that above all takes teachers seriously and seeks to listen to 'the teacher's voice'" (Goodson, 1992, p. 10). The insiders' perspectives and their experiences were of interest to the researcher who had the goal of carrying out research that might help future curriculum change endeavours. The researcher had the confidence to explore the area of physics education as she was a physics teacher within the New Zealand school system and she also had experience in in-depth interviewing of teachers which she had done as part of her Masters thesis (Fernandez, 1991).

The methodology taken for this research falls loosely into what is called qualitative research: “Qualitative research is inquiry aimed at describing and clarifying human experience as it appears in peoples’ lives” (Polkinghorne, 2005, p. 137). Curriculum change affects many people and can be studied in a global quantitative manner to look at the effectiveness, or otherwise, of the change as well as the factors that affect implementation of the change. However, quantitative studies of curriculum evaluations and implementations are limited in their ability to enlighten us on these complex situations beyond the narrow forms of data and interpretations of outcomes of teacher behaviours and student learning. On the other hand, qualitative research has special value in studying curriculum change in that there are clear, logical and articulated relationships between research purpose or aims, methodology and data forms. Qualitative inquiry can uncover deeper level issues and factors that constitute or hinder the curriculum change attempted. The following sections will support this claim.

The next section 4.2 is on general methodological considerations; section 4.3 will elaborate the possible research methods in the light of these considerations; finally section 4.4 will deal with the actual research design for this thesis.

4.2 Qualitative Research

Qualitative research does not denote only one type of inquiry. The different types of qualitative inquiry can be organised under different traditions. For example, Creswell (1998) identifies biography, phenomenology, grounded theory, ethnography, and case study as different qualitative research traditions. The prominence of various traditions of qualitative inquiry can be studied from a historical perspective. Emergence and re-emergence of the different traditions are reflected in the acceptability of the different research methods as valid for data gathering and capable of representing the experience being studied. This can be correlated to the stages of development in the philosophy of social science and paradigms associated with social science research (Denzin & Lincoln, 2000).

4.2.1 Paradigms

Guba (1990) delineated four different paradigms for research inquiry: conventional positivism, postpositivism, critical theory, and constructivism. What distinguishes constructivism from the other three is its ontological view: “realities exist in the form of multiple mental constructions, socially and experientially based, local and specific, dependent for their form and content on the persons who hold them” (Guba, 1990, p. 27). This ontological view is common to the interpretive paradigm distinguished by Lather (1992).

In the delineation of research paradigms, Lather (1992) sets out four groups of inquiry: ‘positivism’ where the purpose is to predict in a scientific manner; ‘interpretivism’ where the focus is to understand the experience (this includes ideas such as naturalistic and phenomenological study); ‘emancipatory’ approaches where the focus is on change (including paradigms such as critical and feminist study); and finally ‘deconstruction’ where the focus is the problem of how the research process itself creates its own structural bounds on our understandings (including post-structuralist and post modernist paradigms). Associated with approaches to research inquiry are various research methodologies. The research methodology chosen is the theory of how to acquire valid knowledge that the researcher works from and it forms the framework that guides the research process.

Ontological and epistemological viewpoints of the researcher play a very important part in their choice of methodology and the methods employed to explore the research area. The beliefs about the fundamental nature of the entities making up the reality being investigated form the ontological stances of the researcher. The beliefs about the ways in which one can come to know this reality or situation form the epistemological stances of the researcher. If reality is considered as existing outside the perceptions of people, that is, being an objectified entity, then a more positivist research tradition will be followed. However, if reality is seen as within the minds and constructions of the people then a more interpretive research tradition will be followed. The ontological stance of the interpretive paradigm sees the experiences and views of the participants as embedded in and evolved from the social, cultural and historical contexts that they are involved in.

As this research seeks to explore the thinking of teachers and curriculum developers, the philosophical stance of the research is located closest to the interpretive paradigm. Critical to this research is acknowledgement of the interactive nature of the inquiry. The issue of subjectivity is not side-stepped but held up as a necessary condition to explore the constructions held by individuals. Subjectivity on the part of the researcher is acknowledged and comes into play during the interactions with the participants. This concept is also referred to as “reflexivity” where:

Reflexivity recognizes that researchers are inescapably part of the social world that they are researching, and indeed, that this social world is an already interpreted world by the actors, undermining the notion of objective reality. ... Highly reflexive researchers will be acutely aware of the ways in which their selectivity, perception, background and inductive processes and paradigms shape the research. (Cohen, Manion, & Morrison, 2000, p. 141)

People constructing their views and experiences based on social, cultural, and historical contexts is the basis for the social constructivist and sociocultural ways of knowing. The key difference in the two is the role of artifacts or objects in the sociocultural interactions that define their experiences. The essential similarity is that reality exists within the constructions and interpretations of the individuals and their social settings.

Social constructivist and sociocultural research are both subsumed under the interpretive paradigm (Cohen & Manion, 1994; Lather, 1992; Smith, 1992). Working within this paradigm, interpretive research centres on individuals and their experiences in situations and in their communities. Interpretivist researchers seek to represent the individuals' interpretations of situations and events involving them. The findings then form the basis of developing theory that can illuminate the understanding of people's behaviour under similar situations and contexts.

In interpretivist research, data is gathered from interviews, observations and, where relevant, the analysis of documents (Smith, 1992). Thus humans are the prime data collection instrument in this research and preferred against non-human devices, such as questionnaires, because of "their greater insightfulness, their flexibility, their responsiveness, the holistic emphasis they can provide, their ability to utilise tacit knowledge, and their ability to process and ascribe meaning to data simultaneously with their acquisition" (Guba & Lincoln, 1982, p. 245).

Guba (1990) highlights two aspects in the methodological process of the interpretive inquiry - the hermeneutic and dialectic aspects:

The hermeneutic aspect consists in depicting individual constructions as accurately as possible, while the dialectic aspect consists of comparing and contrasting these existing individual (including the researcher's) constructions so that each respondent must confront the constructions of others and come to terms with them. (Guba, 1990, p. 26)

The aim is the identification of the variety of constructions that exist of the situation under study with a view to arrive at as much theoretical consensus as possible. Thus researchers, as well as being data gatherers must also be engaged in comparing and contrasting the data from individual respondents in order to arrive at a coherent theory.

4.2.2 Trustworthiness of qualitative research

Denzin (1994) argues that good qualitative research must work differently from those concepts of quantitative research with its validity tied to the positivist concepts of internal validity, external validity, internal reliability and external reliability. Instead he advocates the concept of trustworthiness.

Validity may be an inappropriate term in a qualitative research context if it is taken to simply reflect a concern for acceptance within a positivist concept of research rigor. To a qualitative researcher, validity means much more than the traditional definitions of internal and external validity usually associated with the concept. Traditional quantitative social science research (often based on experimental studies) sees internal validity as relating to whether the measurements and design of research permits conclusions to be drawn about the sample of the study. External validity relates to the extent that any effects seen in the research can be generalised beyond the research context (Burns, 2000). However, it has been argued that trustworthiness is a more appropriate word to use in the context of qualitative research. It is helpful because it signifies a different set of assumptions about research purposes than does the concept of validity (Denzin, 1994). The trustworthiness of research is associated with credibility (establishing research that ensures a plausible credible representation of multiple realities); dependability (establishing a research process with integrity); confirmability (ensuring the research reports the actual data that emerged from the

study); transferability (ensuring that the research provides contextual information that allows readers to ascertain the relevance of the study to other situations).

To avoid validity and reliability claims that are not appropriate in their conventional sense in research within the interpretive paradigm, the 'trustworthiness' or 'authenticity' of the data collected can be enhanced by techniques such as thick description and triangulation (Cohen & Manion, 1994; Guba, 1990; Smith, 1992). The onus is on the researcher to correctly interpret the interpretations of the respondents. Seeking clarification during or after interviews, returning transcripts to the interviewees, as well as noting the respondents' reactions to the researcher's analysis of the data known as respondent validation are some ways of improving the trustworthiness of interpretivist research. In the research report, data can be presented in a context-rich background so that the reader is enabled to make judgements about the applicability and transferability of the information. This contextualising of the data is termed as thick description (Guba, 1990). Triangulation can involve the use of a variety of methods of data collection in the same study so as to add to the researcher's confidence in arriving at the conclusions of the research. It can also involve multiple interviews of the same participant or use of multiple participants undergoing similar experiences. Different types of triangulation and their characteristics are explained comprehensively in Cohen, Manion and Morrison (2000).

4.2.3 Generalisability and transferability

Generalisability is a serious issue in small sample qualitative research. Cohen, Manion and Morrison (2000) suggest that for some researchers, positivist research generalisations that say little about the research context are of not much use. "For positivists variables have to be isolated and controlled, and samples randomised, whilst for ethnographers human behaviour is infinitely complex, irreducible, socially situated and unique" (Cohen, Manion & Morrison, 2000, p. 109). Thus, the contrast in methodological stance about generalisation between research traditions is stark.

A small sample is the ideal size for in-depth qualitative research. As pointed out in Lincoln and Guba (1985), such small samples carry threats to the generalisability of research because they may be distorted by homogeneity in the backgrounds of cases;

homogeneity of case settings, and uniqueness in the historical context of the cases. It is thus important to provide as much thick description and an audit trail that allows for the critical analysis of the path to the analytic conclusions of qualitative research.

The question of whether such qualitative research has findings that can be used outside of the conditions of the research is largely based on the transferability of the research. The reader of an in-depth analysis of a few participants can bring his or her own needs and issues into the fore and find similarities or differences with the research that they are reading about. The term 'fittingness' is sometimes used instead of transferability and conveys the idea that it is the audience of the research report that finds relevance and meaning in the descriptions contained in the report: "... a study meets the criterion of fittingness when its findings can 'fit' into contexts beyond the research situation and when its audience views its findings as meaningful and applicable in terms of their own experiences" (Sandelowski, 1986 as quoted in Koch, 2006, p. 92).

4.2.3 The case study in qualitative research

Case studies as a research approach have been used for a long time in disciplines such as anthropology and psychology (Burns, 2000). However criticisms of this approach especially in the area of reliability had diminished its impact in the past until acceptability of qualitative methods gave it more credibility. Campbell and Stanley (1966) suggest that case studies are of almost no scientific value and that they lead to illusions of generalisable knowledge. That is not the view taken in this thesis as recent discussions of case study research point to its ability to lead to generalisable knowledge (Christie, Rowe, Perry & Chamard, 2000; Ruddin, 2006). As Flyvbjerg (2006) points out, at the very least the case study can lead to falsification (a single instance can falsify a false general hypothesis/proposition). Flyvbjerg also suggests that even where case studies do not permit generalisation, a case study can often convey a proposition by 'the force of example'. Merriam (2001) discounted the need to achieve reliability in studies involving a social context as it is impossible and 'fanciful' to try and achieve it. However, issues comparable to notions of validity and reliability such as those underlying trustworthiness need to be taken into account.

The case study is particularly suited to the interpretive paradigm. “It provides a unique example of real people in real situations enabling readers to understand ideas more clearly than simply by presenting them with abstract theories or principles” (Cohen, Manion & Morrison, 2000, p. 181). It gives specific instances in a wider context and may be representative of the wider context or be an anomaly in it. The value of case study is in giving rich thick descriptions that show the uniqueness, the contexts and the holistic nature of the situation under study.

Part of this research involved ten teachers being subjected to several in-depth interviews and the data collected from these interviews have been summarised and presented under various categories. However, this has the limitation of breaking up the context of curriculum change being studied into piecemeal units, or categories, of analysis. Thus to present a more holistic picture, two of the participants were represented as case studies in Chapter 7 and the rich thick descriptions that resulted can be used to set up the background for understanding the summarised comments of the ten teachers taken as a group in Chapter 8.

In the research reported in this thesis, it is the interpretive qualitative methodology that has been adopted by the researcher and in doing so she has resourced research methods such as will be described in the following section.

4.3 Research Methods

The research methods generally used in qualitative research to gather data are interviews with participants, situational observations, and the study of documents and other artifacts (Polkinghorne, 2005). In the current research, the interview was the primary source of qualitative data. Analysis of documents were carried out for *Physics in the New Zealand Curriculum*, both in its draft and final forms, and for other documents involved with the curriculum change situation. Analysing and understanding the document, *Physics in the New Zealand Curriculum*, were fundamental to this study as the research revolved around interactions with this document and it gave a background to the researcher for understanding the interviews and asking appropriate questions. Informal observations were carried out at a physics teachers’ in-service day involving some of the participants.

This research employed qualitative techniques of data collection. Focused interviews, sometimes called semi-structured interviews (see Cohen, Manion & Morrison, 2000, p. 290) were the main instrument for data collection. The features of the focused interview made it suitable for the present study where the participants were involved in a particular situation, that is, the development and implementation of a new physics curriculum. This particular situation was analysed by the researcher in terms of the significant elements; an interview guide was constructed identifying the key areas of inquiry; and the interview itself was focused on the subjective experiences of the participants involved in the situation. For this research, the experiences and views of the curriculum developers involved in writing *Physics in the New Zealand Curriculum* were elicited by means of focused interviews. The constructions, views and experiences of physics teachers attempting to implement the new physics curriculum were explored mainly by focused interviews.

4.3.1 The interview

Polkinghorne (2005) and others (e.g., Kvale, 1996) have considered participant interviews as the approach that is most used for qualitative data gathering. Polkinghorne highlights the fact that the experiential life of the people involved is under scrutiny in qualitative inquiry. However human experiences are not easily understood at a glance. He describes them as being complex and multilayered. The fluid and dynamic nature of human experiences makes it difficult to study using objective methods such as short-answer questionnaires with Likert scales. There is a need for the introspective, reflective and probing nature of the interview method to allow for exploration of the richness and fullness of the human experience. Emotion is a quality that is exposed well by the interview method; many examples of this are seen in the interview data of this research.

Insights into teachers' interpretations that are yielded at emotional and charged moments of an interview would have been hard to come by using quantitative methods such as Likert scale questionnaires. "Interviews enable participants ... to discuss their interpretations of the world in which they live and to express how they regard situations from their own point of view" (Cohen, Manion & Morrison, 2000, p. 267).

While the interview might be potentially a very useful method of collecting data, it is not easy for everyone to conduct a good interview and there are limitations that need to be taken into account. An awareness of these limitations is essential grounding for researchers using interview methods. A good interview is one where the human experience that is being explored has been allowed to surface in many ways ranging from superficial experiences to much deeper ones. The participant is left with a feeling of being understood and supported in exploring their own feelings about the experience, and their sense of safety and privacy has been assured. The following section will deal with the problems that can be encountered in using the interview as a research tool and will consider ways to diminish them.

4.3.2 Issues when using the interview as a research tool

Using the interview as a research tool is not to be regarded as unproblematic. The very nature of the interview is a dialogue. It involves talking where words and language are used to describe experiences, express feelings and thoughts. However, this is not as simple as it seems. The experience and its description can have a gap as they may be removed in time and space; for example, participants talking about situations in the past. Also there is a continuum of philosophies on how one views the connection between experience and language. “Positions on this issue lie along a continuum from Husserl’s phenomenological idea that experiences precede language to Derrida’s postmodern notion that experience itself is a construction of the language one speaks” (Polkinghorne, 2005, p. 139). Thus if the view is that experiences are embedded in language, then the interview can be viewed as being a perfect tool to explore human experiences. However if experiences are viewed as being more complex than language, then the languaged data collected in an interview will be an inferior reflection of the experience.

Another issue to bear in mind when using the interview as a research tool is that people may not be able to fully reflect their experiences. Denzin and Lincoln (1998) suggest that rather than full explanations of their actions or intentions, subjects of research offer accounts, or stories, about what they did and why. In this view, people are often not perfectly in tune with their experiences and so are not able to express their experiences fully.

Another inherent limitation to the interview as a research tool is that inevitably it will be transcribed and made into text. This process will involve a loss of some information, nuance, emotion and other non-verbal communication when oral data are transcribed into written text (Polkinghorne, 2005). Other ways of communicating data in a report such as in electronic recording formats that capture the emotion and speech of the participant may diminish these losses to some extent.

The researcher has to be aware of these inherent limitations of the interview. To do otherwise would be to write up naïve narratives instead of research inquiry. However despite the limitations discussed, “language is our primary access to people’s experiences” (Polkinghorne, 2005, p. 139) and the interview is still a very powerful tool to gain access to human experiences.

The limitations suggested above and other limitations of the interview method can be minimised by sound use of interview skills by the qualitative data collector carrying out the research. The following section will deal with these techniques that will enable the ‘best data’ to be obtained from the interviews. The term ‘best data’ means data or evidence that is as true a reflection of the experiences being studied as is possible for the researcher to obtain (see also section 4.3.7 on triangulation and trustworthiness of interview data).

4.3.3 Interview skills

One important way of ensuring the procurement of good data is for the researcher to have good interview skills that involve a high level of questioning skills as well as active interpretation as the interview is proceeding. The key components are being a good listener, probing and clarifying without directing answers, and not leading or cueing participants to say what the researcher wants to hear. It is all-important for the researcher to be totally absorbed in what is being said and to seek further explanations when in doubt; that is, be actively interpreting in the process of the interview:

There are skills – physical, social, mental, communicative – that embody the act of interviewing, but those alone will not determine answers to research questions. For such determinations, budding researchers must learn the skill of comprehension, the complex aptitude and competence of reflection and representation which are perhaps ultimately unteachable by any method than trial and error. (Dilley, 2004, p. 128)

Being able to wear or walk in the shoes of the participant, metaphorically speaking, is valuable. This can be accentuated if the researcher is from the same community of practice (Wenger, 1998) as the participants or at least within the same field of experience, though this is not always possible. Being from the same community of practice can enable ease of understanding of what was said, especially if dealing with technical aspects (e.g., the content of the physics curriculum), as there are shared meanings between the researcher and the participant (see Wenger, 1998). Much of the details of environment and other situational influences impacting on the descriptions may be easier to be understood by the researcher.

Good planning based on a sound knowledge of the key components of the interview method is essential for amassing trustworthy and useful data. The following section will lay out the key components for using the interview as a useful qualitative data collection tool.

4.3.4 Key components of the interview

Interviews range in type and form and a key dimension to distinguish them is the amount of structure imposed on the interview situation (see Cohen, Manion & Morrison, 2000). There are a number of interview types but the type often used in qualitative educational research is the semi-structured or focused interview (as opposed to the formal or structured interview and the informal conversational unstructured interview).

The semi-structured or focused interview is based on the concept of being non-directive but it incorporates the need for focus and economies of time in a research context. This is done by prior analysis of the situation being studied by the researcher and thus leading to a focus of areas to be explored. Furthermore, it enables the researcher (interviewer) to evaluate significance of the data being collected while the interview is in progress.

In a focused or semi-structured interview, there are some questions that are predetermined. Other questions may emerge to probe depths of the responses to the predetermined questions, or to clarify interviewee answers. Griffie (2005) lists five

issues and decisions to be made when commencing to interview. The interviewer must decide on:

- whom to interview,
- the number of interviews required,
- the place for the interview,
- which questions to ask, and
- how the data should be collected.

Considerations related to each of these decisions are listed below. These ideas taken from literature on the interview technique in qualitative research have formed the basis for choices made in designing the interviews in this research.

Whom to interview? As the focus of qualitative research is different from that of quantitative research, and claims about a population on the basis of the sample studied is not necessary, random sampling is not ideal. Instead of sampling of the participants from the population, careful selection is involved in seeking out appropriate people who would provide a range of views and ideas on the situation being studied:

Participants and documents for a qualitative study are not selected because they fulfill the representative requirements of statistical inference but because they can provide substantial contributions to filling out the structure and character of the experience under investigation. (Polkinghorne, 2005, p. 140)

However participants are often also chosen due to geographical convenience and accessibility to the researcher.

Number of interviews? One-off interviews may not be able to enlist in-depth sharing of experiences. Usually the first interview is quite restrained and as more interviews are done with the same participant, the atmosphere of familiarity, trust and openness can enable “explorations into the depth and breadth of the experience” (Polkinghorne, 2005, p. 142). Three interviews with the same participant and on the same topic at least have been suggested as producing accounts that are of sufficient depth and breadth (Seidman, 1991).

The place for the interview? The ambience and the artifacts in the surroundings in which the interview is conducted can trigger memory of the experiences being discussed. For that reason the setting for the interview needs to be described (Griffie,

2005). In the case of the writers and the teachers in this research, the interviews were held in their offices, classrooms and for a couple of participants in their homes as was their convenience.

Which questions to ask? This is a very crucial aspect as the researcher is aware of what they want the participants to talk about. There is a focus and particular experiences to be explored. The formation of initial questions to get the participant talking needs to be well thought out and the follow-up and probing questions can also be determined in advance. A written out schedule of questions can be very useful. However in the semi-structured interview, there is a realisation that it is not a question and answer session but a conversation where the “researcher assists the interviewee to explore the experience with open-ended questions” (Polkinghorne, 2005, p. 142). Once again the skilled judgement of the interviewer comes into action. The interview protocol is just a guideline; it can be varied and questions adjusted as seen fit by the interviewer.

The concept of the interview being a process of cocreation is touched on by both Polkinghorne (2005) and Griffiee (2005) since the interview data is affected by the participant as well as the researcher. “The presence and variety of questions posed by the researcher affect a participant’s recall, and thus, the produced account is sometimes referred to as cocreation” (Polkinghorne, 2005, p. 143). The researcher’s questions can instigate the participant to start thinking about some issues not thought about before and come to some realisation of how they feel about those issues. However Polkinghorne issues a warning that the author of the data is still the participant and the researcher needs to minimise their own expectations coming through in the data collected. “They need to manage their influence and bring focus to the participant’s own understandings” (Polkinghorne, 2005, p. 143). It is undeniable that the researcher’s own emotions, attitudes, beliefs, values and other characteristics can enter into the research (Hitchcock & Hughes, 1989). However the concept of reflexivity (Robson, 2002) where the researcher is aware of and open about these self factors can help to reduce the researcher bias.

How the data should be collected? How the data is collected depends on the availability of equipment such as tape recorders and video recorders, and also on the

agreement between the researcher and the participant on the use of the equipment. Taking notes during the interview is another option or just listening only and writing up of the interview later is possible (although the recollection of the interview is likely to be incomplete and selective).

Following the interview, the next stage in the research method using the interview is the conversion of oral language into written text and the analysis of the data. The following section will deal with this very important stage of the research.

4.3.5 Analysis of interview data

Miles and Huberman (1984) dedicated a whole book to the analysis of qualitative data lamenting that it was one area that was not dealt with rigorously and often side-stepped by researchers in not giving clear explanations of what they did to their qualitative data to arrive at their conclusions. They summarise the analysis process to contain three main parts that run simultaneously as well as interrelatedly. These are data reduction, data display, and conclusion drawing/verification.

The raw data in the form of words from the interview are not meaningful in themselves. They need to be interpreted by the researcher. When oral data is transcribed into written text, the meanings represented by the text are what is important and not just the marks on paper (Polkinghorne, 2005). However the meanings are not literally that of the participant's. They are according to Griffiee (2005) a cocreation where the literal words of the participant relate to the questions asked by the researcher as well as the researcher's assumptions and biases. Thus the main job of the analysis of interview data is to develop an interpretation of its meaning. Here huge amounts of data amassed are reduced to bring out the salient meanings of what was discussed. To do this Hitchcock and Hughes (1995) suggest two main strategies: one is to be very familiar with the raw data, going over it many times, such that eventually meaningful categories (grounded in the data) emerge that crunch the data to a few key ideas; the other is to have preconceived categories based on some hypothesis and the data is trained into these categories as seen appropriate. These two strategies are seen as being at two ends of a continuum and the amount of exploratory nature in the study determines the extent of utilisation of a grounded categories approach (Polkinghorne, 2005).

The final process of the analysis is for the researcher to give an interpretation that brings together the themes expressed in the different categories. Miles and Huberman (1984) added another dimension of “verification” to the interpretations or conclusions where these are tested by going back to the raw data or by the more extensive process of “intersubjective consensus” (p. 22) where the conclusions are reviewed among colleagues.

Having described the approach to analysing qualitative data, it is important to note the divergence of the qualitative approach from the quantitative approach with its preoccupation with numbers and the description of the normative. The following section sets out why quantification does not play a part in interpretive research.

4.3.6 Quantification in qualitative interview research

It is important to state that the goal of qualitative inquiry is not to give an exact view of the extent of similar responses. It is to explore the depth and breadth of responses of particular experiences and situations. The small sample size usually maintained in qualitative research puts the focus on to the ideas and thoughts expressed by the participants. Polkinghorne (2005) provides a number of cautions against quantifying responses in qualitative data:

Participants and documents are not selected because they fulfill the representative requirements of statistical inference but because they can provide substantial contributions to filling out the structure and character of the experience under investigation. ... Qualitative studies vary in the kinds of experience they investigate; yet, their interest is about the experience itself not about its distribution in a population. (p. 139)

Polkinghorne (2005) also clarifies that the value of having multiple informants in qualitative enquiry is for the possibility of investigating human experiences more deeply:

Qualitative findings are not directed to determining the most likely or mean experience within a group but to describing the aspects that make up an experience. ... The use of multiple participants serves to deepen the understanding of the investigated experience; it is not for the purpose of

making claims about the distribution of the experience in a population. (p. 140)

Kvale (1996) in his book on interviews lends support to this view by stating, “The interview seeks qualitative knowledge expressed in normal language, it does not aim at quantification” (p. 30). Thus, by seeking the depth and breadth of human experience rather than quantitative midpoints, the qualitative knowledge obtained has added trustworthiness. The next section considers how triangulation can also add to the trustworthiness of qualitative research

4.3.7 Triangulation and the trustworthiness of interview data

The interpretation of the situation or experience under study by the researcher as part of the data analysis is not random and needs to be subjected to a validation process. The inherent limitations of the interview for data collection cannot be altogether eliminated, though a skillful interviewer can minimise its effects. However, triangulation and reinterviewing can be used as two means of validating the data (Hitchcock & Hughes, 2005). Triangulation can be done by comparing two sources of data (Griffie, 2005). This can be done by interviewing the same person a number of times over the same topics or by interviewing multiple participants about the same topic. The consistency of their comments can strengthen the trustworthiness of the findings. Also, when interviewing the same person over a period of time, the consistent correlations in their comments can illustrate developmental consistency. Another way of increasing trustworthiness of the data is to undertake reinterviewing. Here, an initial summary or interpretation can be returned to the participant and a further interview conducted for the purpose of clarification.

Triangulation can also be done by utilising alternative methods of data collection such as observations and document analysis in order to supplement and clarify the data collected from interviews. The following section will briefly describe the use of observations and documents as techniques of data collection.

4.3.8 Data from observations and documents

Observation is a method of gathering data that is at the core of sociological and anthropological studies. When conducting an observation, the researcher watches the

participant in action and records behaviours every few minutes or just focuses on targeted behaviours to be studied. However, when interviewing is used as the main data gathering tool, observations from within the interview context can help to enrich the interview data gathered as well as validate it. Observational data can be about the person of the participant such as “behaviours, facial expressions, gestures, bodily tone, clothing, and other non-verbal indications” (Polkinghorne, 2005, p. 143). The observational data can also be about the environment where the interview is being held or where the behaviour is being studied. Thus a description of a “participant’s home or office, the furniture arrangement, displays of photos and pictures, books, magazines, and other reading materials can serve as indicators of a participant’s experience” (Polkinghorne, 2005, p. 143). The observational notes will need to be in written form and attached to the interview as memos. Once again the skills of the observer will determine the quality of the observational data and this requires training and experience.

Good observation during an interview can provide data towards a form of triangulation that often adds to the integrity of the interview data. Observational data from interviews also provide contextual cues for deeper understanding of what was said at the interviews when the processing of the interview data occurs at a later date.

Another important source of data is in the form of analysis of documents. Documents can shed light on the area being studied and be very valuable to enlighten the researcher on the important aspects to concentrate on when planning for the interviews. They can become an integral part of the research both in the planning and in the analysis stages of the research. Within the sociocultural framework, documents can be viewed as cultural or communication artifacts (Salomon & Perkins, 1998; Wenger, 1998). Their impact on behaviour is the basis of a number of sociocultural studies. Polkinghorne (2005) widens the scope of documentary evidence to cover literature reviews done when commencing on research as a type of qualitative research:

The documents selected for data are from the scientific literature related to the research question. An analysis based on qualitative principles is used to identify the essential themes and variations that have appeared in the body of previous research. (Polkinghorne, 2005, p. 144)

Thus, while the interview is an important source of qualitative data in interpretive research, it can be supplemented by observational and documentary data so as to enhance the trustworthiness of the data collected. In all this, the researcher needs to remain focused in presenting the perspectives of the participants. This means that the ethical issues involved in using the interview as a research tool are very important considerations. These will be dealt with in the following section.

4.3.9 Ethical issues in educational research using interviews

Conducting educational research, especially using qualitative methods, is not unproblematic. Burns (2000, p. 23) cautions that “ethical problems are likely to occur in social science research since human subjects are involved. Researchers must be aware of ethical considerations involved in voluntary and non-voluntary participation, deception, informed consent, privacy and confidentiality, the right to discontinue, and obligations of the experimenter.”

The key ethical considerations are summarised very succinctly in that quote by Burns. Involvement of participants should be voluntary. They should know what the research is all about and their role in providing the data. There should not be misleading information to deceive the participants as to their actual involvement in the research. Any risk or harm anticipated for the participants need to be acknowledged and minimised. Thus issues of privacy and confidentiality are of utmost importance. The anonymity of the participants needs to be guaranteed especially when dealing with sensitive situations. Also issues of stress and extra work on participants imposed by their participation in the research need to be aired between researcher and participants. The rights of the participants need to be highlighted at the beginning of their involvement in the research, such as the participant should be free to withdraw from participating in the research at any time without penalty; and the right to not disclose or write up some parts of their interview, for example, have the tape recorder turned off at request from a participant at certain points in the interview.

The interview explores the many layers of meaning of experiences of the participants. It delves into the professional and personal lives of people. “Interviews have an ethical dimension; they concern interpersonal interaction and produce information about the human condition” (Cohen, Manion & Morrison, 2000, p. 292). Three main

areas of ethical issues identified by Kvale (1996) are informed consent, confidentiality, and the consequences of the interviews. Prior to commencement of any research interviews, the informed consent of the participants should be received preferably in writing. By informed consent, the participant is aware of what the interview covers and what they are being used for and then volunteers to be part of the research.

The ideas, thoughts and feelings divulged in an interview have to be held as sacred, that is, be represented as faithfully as is possible, given the background and biases of the researcher. Even if a particular type of response has only a single voice to it, that response is taken as an integral part of the data as it enriches the understanding of the situation under study. The researcher needs to demonstrate reflexivity by becoming aware and open about their own hypotheses or bias and how that will affect the interpretation of the meanings being conveyed during the interviews and also during the analysis process (Robson, 2002). The confidentiality of the participants should be upheld if they want it so, and the ownership of the data needs to be clearly kept within the authority of the participants.

Despite the participants retaining ownership of the data collected, often the researcher has “considerable leeway in the selection and process of developing these data” (Polkinghorne, 2005, p. 144). The onus is thus on the researcher to analyse and present the data with integrity and honesty, keeping to the perspectives of the participants, and make clear and transparent the process of production of that data. Only then will the data be trustworthy enough to be useful for those who will be reviewing it as well as those who wish to use the findings in their practice (Polkinghorne, 2005).

Returning of interview transcripts to the participants and reinterviewing or clarifying any anomalies will enable greater trustworthiness of the research data. Also the ownership of what was discussed in the interviews is handed back to the participants in this situation.

Informed consent is a very important principle in ethical considerations for the researcher to abide by (Cohen, Manion & Morrison, 2000). To that end, much of the documentation of ethical considerations, risks, benefits, rights, etc. can be supplied

with the information about the research and participants can then provide their informed consent. Most educational institutions or organisations that undertake research will have their specific guidelines for ethical considerations when conducting research. The ethics statement for this research conducted under the University of Waikato will be explained in section 4.4.8 that follows in the description of the research design.

4.4 The Research Design

4.4.1 Focus of the investigation

This investigation explored and analysed the new senior physics curriculum in New Zealand schools initiated by the Ministry of Education from its development in 1993 to its official implementation in 1998 (see Figure 3 for a timeline of this investigation). *Physics in the New Zealand Curriculum* was the first ever curriculum document written for senior physics in secondary schools in New Zealand. In the past, the senior school physics curriculum was based on the physics examination prescriptions that were mainly a list of content topics to be assessed in internal and external examinations. At the same time, new assessment procedures were being developed by a separate statutory body called the New Zealand Qualifications Authority (NZQA) who established the new National Qualifications Framework (New Zealand Qualifications Authority, 1992a). This was a standards-based approach to assessment and led to the setting up of Unit Standards. Unit Standards are a form of assessment against standards defined by performance criteria for the achievement of various units of learning outcomes. The existing mode of national examinations such as School Certificate and Bursary examinations for senior physics continued with new prescriptions for them based on *Physics in the New Zealand Curriculum*. In the meantime the Physics Assessment Guide (New Zealand Qualifications Authority, 1996) was produced with guidelines and sample Unit Standards for teachers to trial. Some pilot schools had trialled a few Physics Unit Standards in 1995 and this was used as the basis for the Assessment Guide. Teachers who trialled the Unit Standards had to contend with doing dual assessment as the existing national examinations were still in place. It was a time of great uncertainty where both the curriculum writers and the teachers were unsure of the future of the assessment procedures. It was only in November 1998 that the then Minister of Education, Wyatt Creech launched the new

school qualifications for 16 to 19 year olds called 'Achievement 2001'. He explained that the new National Certificate of Educational Achievement (NCEA) will progressively replace existing assessments for Years 11, 12 and 13 (i.e., School Certificate, Sixth Form Certificate and Bursary) starting with Year 11 in 2001 (New Zealand Qualifications Authority, 2001).

In-service courses and school-based workshops were carried out to familiarise teachers with *Physics in the New Zealand Curriculum* and Physics Unit Standards, and the stage was set for the implementation of these in the classroom in 1998.

This research views the teacher as the vital link in the development and implementation of a new curriculum. Its main focus was on understanding the impact of *Physics in the New Zealand Curriculum* on the interpretations that physics teachers made of the new senior physics curriculum and the impact that it had on their classrooms. The effects of the national assessment requirements, namely School Certificate and Bursary examinations, and the trialling of a new assessment, Unit Standards, on the implementation of the new curriculum were also addressed in the research. The research intended to compare and contrast the interpretations of the physics curriculum by the teachers with the interpretations of the physics curriculum intended by the curriculum developers, in particular the three writers.

Another intention of the research was to develop a model of curriculum change that described the change processes associated with the new physics curriculum. The model was based on the data collected and the theoretical underpinnings in analysing the data, and extended to incorporate a wider scope of viewing this important field of curriculum change. Finally the research was to explore the usefulness of the model to highlight situations that could be improved to address the needs and concerns of teachers involved in the change, so as to enhance the effectiveness of a curriculum change initiative.

4.4.2 Data collection methods

This research explored the development and the implementation of a new physics curriculum in New Zealand and involved three curriculum writers and ten teachers. It

was conducted within an interpretive qualitative research paradigm because it sought to explore the interpretations of the insider participants of a curriculum development and implementation situation.

Curriculum Events

Research Events

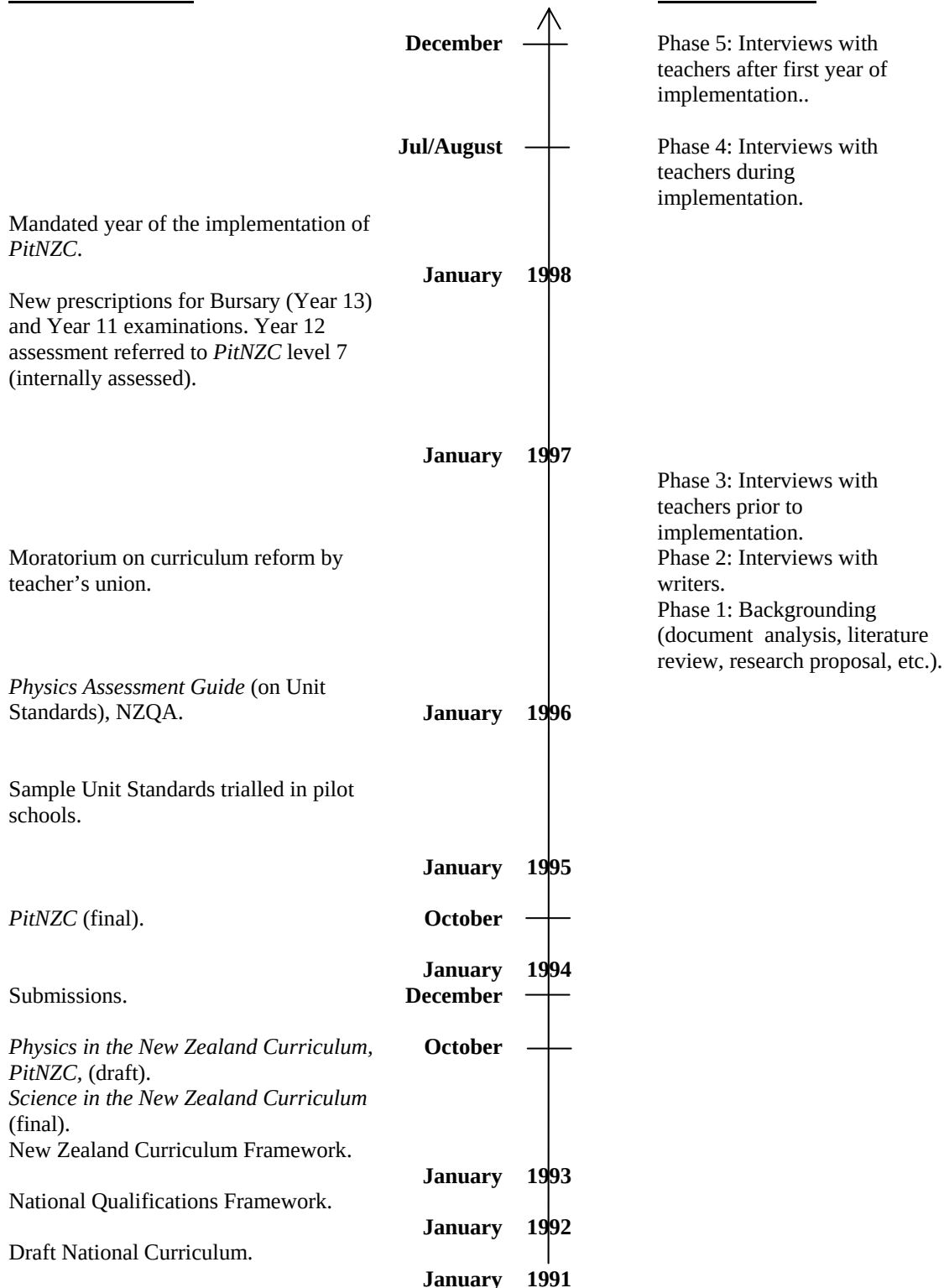


Figure 3: Timeline for curriculum, assessment, and research

The research method most useful for gathering data of insider interpretations is the focused interview (Cohen, Manion & Morrison, 2000). In the current research, the participants had been involved in the development and implementation of a new physics curriculum. The researcher was interested in obtaining an insider's point of view; thus the interviews covered the subjective experiences of the participants involved in the situation. The interviews were semiformal conversations that revolved around areas considered relevant to the research which were framed as questions in an interview schedule. An interview schedule was generated for each round of interviews and had a central role in guiding the interviewer. Essentially literature research data (see Chapter 2) led to the identification of salient aspects of the curriculum change situation. This led to the development of research questions (see Chapter 3) that broadly covered these aspects. The research questions set up the focus of the areas to be explored in the interviews. Specific questions were formulated for the different areas and written up as an interview schedule. The questions in the interview schedule were discussed and refined with my supervisors for their appropriateness and finalised with the understanding that the questions may be reworded and their order rearranged to enable the smooth flow of ideas during the interviews.

As *Physics in the New Zealand Curriculum* was the pivotal document in the curriculum change being researched, I analysed the document to get an understanding of its structure and content. The study of the document enabled the development of appropriate interview questions that referred to the document. Thus, before the interviews were carried out, a review of *Physics in the New Zealand Curriculum* was done by the researcher for both the draft version and the final version. The draft and final documents were compared for changes, and additions and deletions were noted. Access to the submissions made to the draft document was useful in understanding the final version. This enabled an appreciation of what was written in the document and gave indications of what areas to explore about the various aspects of the curriculum document with the writers in their development of the document and with the teachers in their interpretation of the curriculum document.

There was also an informal observation conducted of a physics in-service course for teachers organised by the Education Support Services. This too provided insight into the physics curriculum document and the interactions with it by the teachers. As a

further form of backgrounding for the researcher to have heightened awareness of the many facets of the situation under study, I talked to a variety of people involved in physics education such as persons on the Policy Advisory Group, Physics Unit Standards writers and moderators, Science Advisors involved with teacher development with regard to the new physics curriculum and other physics educators before and during commencement of the data collection. Their accounts were not analysed formally but gave the researcher some useful insights into the background of the curriculum change situation which enabled better informed interviews with the writers and the teachers.

The issues of triangulation resulting in trustworthiness and consistency of data collected were accommodated by conducting multiple interviews over a period of three years with the same teachers and also interviewing multiple participants involved in the same experience. The interviews were audiotaped with the permission of the participants. The data from the audiotaped interviews were analysed and formed the basis for further exploration in the later interviews. This allowed the researcher to further question participants in order to clarify and comment further on earlier statements. Thus, this was an iterative process of delving deeper into the issues regarding curriculum change and teacher change. In this way respondent validation was maintained.

The three writers of the curriculum were approached directly and individually through an invitation letter to participate in the research. The ten teachers were approached via their school principals. Once permission was given by the principals for the teachers to participate in this research, the teachers' informed consent (see Appendix B) was sought directly. All further communication was directly with the teachers.

The lengthy period of interview interactions with the teachers engendered an atmosphere of ease of communication and trust. The three interviews with the teachers were each about one to two hours long and they spoke frankly, giving rise to raw emotions at times. Even the one-off interviews with the writers of the physics curriculum document managed to elicit deep and sensitive issues as evidenced in the data presented in Chapters 5 and 6. This may have been because the interviews were long (2 to 3 hours), the researcher was experienced in in-depth interviewing, and the writers were very willing to share their experiences quite frankly.

The ethical considerations in using the interview as a research tool were upheld including informed consent where the participants were given information on the research, its purpose, their role in providing data, their rights of withdrawal and control, and safety. Most of this information was given in writing at the time of inviting participation, and their signed consent was elicited.

In summary, this research employed qualitative techniques of data collection. Focused interviews were the main instrument for data collection supported by document analysis. Data collection continued through the five phases in the research design and the analysis of the data was conducted parallel to the data collection as the intermediate conclusions were useful in the subsequent phase of the data collection. The next section will deal with the phases of the research.

4.4.3 Phases of the research

Phase 1: Backgrounding

Phase 1 involved reviewing relevant documents, namely the *Physics in the New Zealand Curriculum* draft and final statements, the written submissions from teachers and other stakeholders, the *Science in the New Zealand Curriculum* statement, and the *Physics Unit Standards* and its *Assessment Guide*. Review of relevant literature was also undertaken in this phase, though this continued throughout most of the research.

A detailed research proposal was written up and submitted to the Higher Degrees Committee at the university. The ethical considerations were carefully weighed, written up and submitted for approval of the research which was granted by the School of Science and Technology Human Research Ethics Committee in 1996.

Further backgrounding for the researcher to gather more background information on this situation of curriculum change was carried out by casual interviews (talks) with persons involved in the physics curriculum and assessment changes. These were other than the participants of the research.

To gather participants for the research, invitations were sent out to principals of secondary schools in and around a New Zealand provincial city requesting the participation of their physics teachers in the study. Included in the envelopes containing the principals' letters were invitations to physics teachers, requesting their participation, with an attachment containing an explanation of the research. The principals were requested to pass on this invitation to their teachers if they gave approval for their participation. Ten teachers agreed to be participants in the research and they gave signed agreements to participate satisfying the requirements for informed consent.

Similarly invitations were sent out to the three writers of *Physics in the New Zealand Curriculum* explaining the research and requesting their participation. All three writers agreed to participate in this research.

Phase 2: Interviews with writers

Phase 2 involved focused interviews with the three curriculum writers individually. Although the interviews with the writers were single interviews, they were prepared to share quite deeply about what happened, their joys and frustrations with the process of developing the curriculum document. The interviews were long, ranging from two to three hours, in one sitting. With the curriculum writer who was the unofficial coordinator of the writing group, the interview was longer as the researcher had to return a second time to complete the interview. The researcher had to travel some distance to do the interviewing and the locations were at the offices of the writers, two of whom were teachers at schools and one was at a College of Education.

The interviews were audiotaped with the permission of the participants; on a couple of occasions, requests were made to turn off the tape-recorder so that the participants could give vent to thoughts that they did not want reported. The researcher did not take notes but had a schedule of interview questions that enabled a smooth flow of the conversation (see Appendix C1). The researcher concentrated totally on what was being said and reflected what was being said to seek clarification or to delve deeper into the issues being raised. The level of trust and honesty engendered by the interviews gave rise to a huge amount of valuable data that is presented in Chapters 5 and 6 in this report. The oral data from the interviews were transcribed and the

transcripts returned to the writers for their confirmation and clarification. This method of member checks added to the trustworthiness of the data collected.

Phase 3: Interviews with teachers prior to implementation

Phase 3 involved initial interviews with ten physics teachers. These interviews focused on teachers' perceptions and interpretations of the new senior physics curriculum, in particular, the various sections in *Physics in the New Zealand Curriculum*, prior to the official implementation in 1998. Teachers' views on the professional development that had occurred so far for the new curriculum were also elicited and some of their theories about physics teaching, learning and assessment were also explored in these interviews. Some current issues and debates in physics education were also discussed. The interview schedule used in these focused interviews is attached as Appendix C2. The order and wording of questions were not adhered to mechanically and were varied according to the discussion.

As explained earlier, signed informed consent was obtained and the interviews were one to two hours long and held at various locations according to the convenience of the teacher; the interviews were mainly held at the teachers' schools after their school day, two teachers preferred their interviews to be conducted from their homes and one interview was conducted at the researcher's home as suggested by the teacher. All interviews were audiotaped; the teachers gave permission for that and knew of their right to have the tape recorder turned off or a segment of their interview not reported if so desired. Also they were aware of their rights to confidentiality and to withdraw from the research at any stage without penalty.

The audiotaped data were transcribed verbatim and transcripts returned to the teachers for their checking. The teachers' transcripts were also analysed and the interim findings were discussed with the teachers during the subsequent interviews. Each teacher was interviewed three times in the span of three years.

Phase 4: Interviews with teachers during implementation

Phase 4 involved further interviews with the physics teachers during the first year of implementation of the new curriculum. This was postponed by a year to 1998 due to delays caused by the moratorium on the curriculum reforms imposed by the Teachers' Union in 1996. The second set of interview questions was informed by the data from

the first set of interviews. The focus of the second interviews was to explore how the new teaching schemes were written; whether any significant changes were incorporated into their new schemes; and how the implementation was proceeding. The interview explored the effect of supports or constraints of school structures, resources, and feedback from students, parents and/or colleagues on the implementation of the new physics curriculum. The interview schedule used in these focused interviews is attached as Appendix C3. Similar protocols used for audiotaping interviews were used as described in the Phase 3.

Phase 5: Interviews with teachers after the first year of implementation

Phase 5 involved interviews with the ten teachers on their reflections after their first year of implementation of the new physics curriculum. The third set of interview questions was informed by the data coming from the first and second sets of interviews. Teachers were invited to explore the changes that they have made in their teaching and their ideas about physics teaching as a result of implementing the new physics curriculum. By this stage there was an opportunity for the researcher to attend an in-service course for physics teachers run by one of the writers. The in-service course formed the basis for some of the discussion in this set of interviews. The opportunity to attend the in-service course arose unplanned and the researcher gained permission from the Science Adviser to attend it. Teachers' own backgrounds in learning physics were discussed and their implicit beliefs about teaching, learning, physics and assessment were further explored. Their plans for the future with regards to physics teaching were also elicited. The interview schedule for the third set of interviews is attached as Appendix C4.

4.4.4 The participants

The main participants of the research were the three writers of *Physics in the New Zealand Curriculum*, and ten physics teachers in and around a New Zealand provincial city. All three writers of the physics curriculum agreed to participate. Personal details of the writers will not be divulged as that could easily identify them; it is suffice to say that they were two teachers and one lecturer at a College of Education. They will be labelled as Writer 1, Writer 2 and Writer 3 to distinguish their comments in the data collection interviews.

The sample of ten teachers was established from the responses to invitations sent out to secondary schools accessible to the researcher. The criteria for sample choice were that the participants were physics teachers involved with teaching physics at secondary schools that were handy to the researcher (sometimes referred to an ‘opportunity sample’). As all physics teachers had to be involved in the new physics curriculum implementation, they were all possible participants. Letters were sent out to all the secondary schools in the region as there were not many physics teachers in each school and whoever agreed to be involved in the research was accepted. No discrimination was made along any other criteria except being conscious of wanting some female teachers included as well. As the number of female physics teachers was very few, the researcher was careful about the inclusion of females in the study; there were two in the present study.

All teachers in the research came from urban schools including four State schools, one Integrated school and three Private schools. Two schools had two teachers each taking part in the research. The decile rating for the schools (i.e., an indicator of the socio-economic background of the students where 1 denotes low and 10 denotes high) ranged from 3 to 10 where three of the schools had a decile rating of 5 or below. Four of the teachers changed schools during the period of the research but fortunately they were still within the range of the researcher and continued their participation in the research.

Two teacher participants who started at the beginning of this research withdrew partway through the study (after the first interview); one because he was going on study leave during the year of implementation of the new physics curriculum, and the other exercised his right to withdraw and did not supply any reason for doing so. Two new participants (Ingrid and Jack) joined the research study in 1998 and catch up interviews were conducted with them. The data from the withdrawn participants were not included in this research.

The confidentiality of the ten teacher participants was assured and so their comments are labelled with pseudonyms for anonymity in this report. The next section will provide some information on the ten teachers so as to better understand their background that informed their comments in the following data chapters.

4.4.5 Starting point for teachers

The teachers in the study ranged in terms of number of years of physics teaching experience and teaching style. The following list describes each teacher in terms of their physics teaching background, and in terms of the way that they described teaching occurring in their classrooms.

Andy

Andy had taught for 21 years. His specialisation was in physics and he had taught Year 12 and Year 13 for all those years of teaching. He had been teaching for eleven years at his present school.

In terms of his choice of teaching method, he incorporated a variety, using a video, doing an investigation, or “chalk and talk”. Andy reported that most of the time he was in control and directing the lesson. For the rest of the time, students undertook practical investigations or their own project or research. The project work was guided and an assignment brief was given with particular parts and questions to be dealt with.

Brian

Brian had taught 18 years at his present school. He had about 27 years of teaching experience in all, but had only 18 years of physics teaching. He had majored in chemistry but has done stage two (second year university) physics papers. Brian said that he taught from a list of contents based on past exam prescriptions, and had developed his own style of teaching which he was comfortable with. He explained that his teaching style was quite a lot of “chalk and talk”, a lot of questioning, overhead projector use, workbooks, lots of demonstrations and practicals. He described himself as being more traditional than the newer breed of teachers as he did not include small group discussions, debates and such in his lessons. However, he said that he does bring everyday examples into his teaching topics.

Cathy

Cathy reported that as a beginning teacher, she started with Nuffield Physics in England in the 1970's. She had not done any teacher training and was thrown into teaching straight after her degree study. She described Nuffield Physics as a “wonderfully set up scheme” related to everyday life. She said that as a consequence

of her Nuffield experience, when she came out to New Zealand, it was a bit of a culture shock to find that physics here was very much more theoretical.

Her usual pedagogy was to look at physics concepts and then see how those get used in various components in physical appliances rather than the other way around. Her teaching style was to try and relate concepts to what the students already know. Thus her existing practice was to do a demonstration based on the topic being studied, have students give their views of what was happening and then she would initiate a discussion; then the theory was taught and notes were given at the end of the lesson.

Danny

Danny had been teaching physics for 13 years in 1996. His background was in engineering. He had been a science adviser when the science curriculum document was introduced. His normal mode of delivery starts off with a demonstration followed by some experiments and then the applications of the concepts rather than starting the topic off using a context. Danny was a strong advocate for having a variety of teaching methods. His variety included question and answer sessions, a concept map, discussions to find out what students already knew, practical demonstrations, students dealing with some equipment and discussing the learning, traditional ‘chalk and talk’, and group work with reporting at the end of it. He admitted that some techniques were easier to handle than others. He did not have a consistent way of using these methods; the method he would use would depend upon what he thought was appropriate for the topic.

Eddie

Eddie had been teaching Year 12 physics for six years and Year 13 physics for two years. He had taught physics for some years overseas prior to that too and his qualifications were in physics.

His teaching style was still quite teacher-centred and very traditional – he exposed the students to the basic ideas and then allowed them to do practicals related to that concept. There were not many investigative-style lessons in his class.

His usual teaching style for a theory lesson involved starting the lesson with difficulties faced in the previous lesson; then he introduced some basic concepts, gave

notes, worked out questions to reinforce what was taught and then he would give some homework. A practical lesson involved following a worksheet with instructions given and writing out the report to be handed in that day or the following day.

Fred

Fred had taught for 39 years, of which he taught in New Zealand for 19 years doing senior physics. Chemistry had been his major and physics had been his subsidiary subject. He taught physics because he was forced to do so although he was unconcerned about what subject he was to teach. At the time of the interview he was planning to retire so he was not interested in being involved with the new physics curriculum any further.

Fred reported that he was now a very interactive teacher, conscious about the changing world. He suggested that one of his successes as a physics teacher was that he did not only talk about physics concepts, but that he would always talk about the interaction of human beings with the ideas in physics.

Every year he renewed or changed the assessment tests and assignments for his classes. However he reported keeping the laboratory practicals the same.

Gary

Gary had taught senior physics for two years and physics as part of modular science for the last four years. He had been developing an interest in physics and had decided to specialise in teaching physics. He was a primary trained “all-purpose” teacher who started off as a part-time science teacher six years earlier. Gary did not have any formal training on how to teach physics but he had a helpful Head of Department and the support of other staff.

Gary’s style of teaching physics involved solving problems, doing some experiments and getting students to collect their own data. He found the examples in the textbook good and they gave him ideas for his lessons. There were eighteen physics laboratory practicals done each year in Gary’s Year 12 class which started from basic measurements and developed to more complicated experiments such as the current balance. He liked the development in student learning that he saw with his programme and did not think that such development would be seen if he taught using contexts.

Gary worked from a scientific method framework where there is observation, measurement, and drawing conclusions from the results. He preferred to do this with simple activities and leave it to the students to explore any further contexts if they wanted to.

Henry

Henry considered himself relatively a “spring chicken” in the physics area as he had taught for only about nine years including two years as a science adviser. He was the backup teacher for a physics expert in his school and just taught sixth form physics.

Despite being a science adviser where he advocated student-centred methods including contextual teaching, he found that he was still “guilty” of teaching the pure physics part first before relating it to real world situations. He described himself as the sort of person who teaches physics by getting a washing machine, pulling out the inside mechanism and switching it on to see how it works.

Ingrid

Ingrid was trained as a radiographer and had worked in New Zealand and overseas as one. Wanting a change in career, she completed her science degree majoring in physics and then entered Teachers’ College and started teaching in 1992. Subsequently, she worked as a physics teacher part time and full time. Her teaching career had been interspersed with having children and on the whole she had taught physics for five years. She said that she was happy teaching senior physics and enjoyed it.

In terms of historical ideas and applications in society, Ingrid said that she always developed some topics along historical outlines and in Year 12 physics she used a lot of examples from everyday life. Her training has been to teach from a more interactive view. She was not from the old school and had been trained in junior science. She felt that the changes in the physics curriculum were just a lead on from the way that junior science had been moving during her training.

Jack

Jack majored in physics but had also done chemistry and mathematics. He had taught for about 25 years. He had taught for 21 years at his previous school and had spent

only one and a half terms at his new school. Jack had been a facilitator of a Science contract about five years ago. He had developed an assessment schedule that was quite meaningful according to him.

Jack reported that he had always had hands-on teaching and learning in his classroom. He thought that his students got a good grounding in terms of practical physics. His style was such that he could not stick to prepared OHT notes, but rather tended to go along with the interest of the class and follow through the students' questions. He would catch up with the planned lesson later on. He was interested in group work and assessment, and had tried it with the students.

4.4.6 Analysing interview data in this research

The interviews, when transcribed, produced hundreds of pages of transcripts. The participants are quoted verbatim from these transcripts in this thesis. The transcripts were returned to the participants for their clarification and further comments. Analysis was an on-going process. After the first set of data was collected it was analysed to inform the next set of questions for the second round of interviews with the teachers. This was in accord with suggestions in Glaser and Strauss (1967) and Miles and Huberman (1984). Finally all the checked data were analysed and theorised.

Wellington (2000, p. 143) describes "immersing" oneself in the data as "hearing or reading it, and re-hearing or re-reading it, over and over again. Gradually we then begin to make sense of it and begin to categorise and organise it in our minds." There was a prolonged period of "immersing" myself in the data, where I got 'under the skins of the participants'. I found this especially useful as I began to have a strong sense of what the participants were saying, and the underlying issues that they faced in developing or implementing the new physics curriculum for their classrooms. It helped in interpreting what they were saying at the interviews. My interim interpretations were presented at two departmental seminars during the course of my research where the comments and feedback from my colleagues were very useful.

The analysis started with coding (see Cohen, Manion & Morrison, 2000). Each passage or paragraph or even a sentence in the transcripts was given a unit of

meaning. Each paragraph in the interview transcripts was analysed for the point they made; these were written by the side of the paragraphs. The themes that emerged with respect to the areas of inquiry were noted and they formed headings for the categories. This was an inductive process (Wellington, 2000, p. 149). As well as the search for regularities, data was also compared and contrasted to ensure that the categories developed also reflected irregularities in the data. (The methods of comparison, Glaser and Strauss, 1967, and contrast, Delamont, 1992, are interrogative methods used in analysing qualitative data to search for irregularities as well as regularities and themes in the data.)

The coded meanings were clustered under categories. These categories emerged from the groups of meanings evident in the data and also from categories derived from preparatory readings when reviewing literature in the areas of curriculum change and teacher change. The data from the interview transcripts for the individual teachers were all analysed and located under the different categories. Some of the data straddled a couple of categories but most of the data could be located in just one category. A synthesised list of seven categories of criteria for teacher change derived from the literature review was used to subsume the categories on emergent issues that arose out of the interview data from the teachers and the writers. Through this process, the interview data was related to extant theories of change.

In writing up the interviews, summaries were written to compare and contrast different views under the emergent categories. A narrative was then woven to link and structure the categories to describe the various facets of the situation under study. Finally, the interview data were interpreted, bringing together theories in that research area and findings from the data. The findings of the research were also used to generate new theories to illuminate this complex field of curriculum change and teacher change; and the conclusions led to implications for policy makers and practitioners in that field as well as directions for future research.

The case studies in Chapter 7 enabled the stories of two of the teachers be told in full. The reasons for their choice will be explained in that chapter. They are included in the thesis to provide a detailed and more holistic picture of how two teachers responded to the curriculum document. This is to complement Chapter 8, which separates and summarises comments made by all the ten teachers under various categories. The

actual development of theory advanced in this thesis based upon the data is described in Chapters 9 and 10.

4.4.7 Movements in the data stream

The research questions (see Chapter 3) were used to guide the compilation of the interview data accumulated as well as to separate out the useful data from what was to be discarded. As the initial data collection took a wide sweep of the field, I needed to narrow it down to some useful issues of curriculum change and teacher change specific to *Physics in the New Zealand Curriculum*.

The data collected also influenced the theoretical perspective that I, as researcher, held on entering the data stream. Although I started from a social constructivist theoretical perspective, I moved to a sociocultural perspective as I found that it better described the field that I was looking at. In particular, Wenger's ideas found in his book *Communities of Practice* (1998) were found to be useful in describing and analysing the process of curriculum change within which teacher change is enfolded. His ideas were used to design a model of curriculum change that described the situation of a mandated curriculum change, that is, where the curriculum change was initiated from outside the school; in this case it was initiated by the Ministry of Education.

Throughout the analysis in this research, I have kept in mind that it is possible to analyse any phenomenon in more than one way (Spradley, 1979). The current research as well as representing the data provided by teachers also contains my own image as researcher. In my analysis, I try to indicate the beliefs I hold, the paradigm I am located in, and the tools I employ. To do so is to add to the trustworthiness of the conclusions of my analysis. Trustworthiness of the data is also accentuated by keeping to the ethical considerations of qualitative research. Participants should feel safe and secure enough to share their deeply held views and also be in control of what they share. The following section will describe the ethical considerations undertaken in this research.

4.4.8 Ethical considerations for this research

At the beginning stage of this research, when the research proposal was being submitted, an application to the School of Science and Technology Human Research Ethics Committee was made. It outlined a description of the project where its justification, objectives, procedure for recruiting participants and obtaining informed consent, procedures involving the research participants, and procedures for handling information and materials produced in the course of the research were included. The ethical concerns such as access to participants, informed consent, confidentiality, potential harm to participants, participants right to decline, arrangement for participants to receive information, use of information and conflict of interest, if any, were detailed and finally an ethical statement was made. The ethical statement read as follows:

In conducting this research the following ethical principles will be adhered to:-

- obtain the informed consent of the teachers and others involved in the interviews.
- ensure confidentiality of data collected.
- ensure that the transcripts of interviews and draft reports are sent to the participants for their comments and these comments are taken into account before publication.
- acknowledge the contributions others have made towards the research and scholarship.
- critique the work of other scholars in ways that are professional and ethical.
- follow the University's policy on equal opportunities and harassment, including sexual harassment.
- maximise the benefits to the teachers of being involved in the research.

Confidentiality of the participants was held in the highest regard. Their transcripts were labelled anonymously and kept in a safe place. At all times teachers had control over what they said, over the audiotaping of their interviews, where they were interviewed, the length of the interviews and also the transcripts of their interviews. They were aware of their right to withdraw from the research at any time with impunity. Care was taken that the professional lives of the participants, especially the teachers, were neither augmented nor diminished in the eyes of their colleagues or

principals. The teachers were fully informed of the nature of the research and their agreed involvement in it was obtained by signed consent.

The legal issues with respect to copyright and ownership of data and materials produced from this research were also considered with the acknowledgement that the researcher owns copyright on her thesis and papers based on the research, and the research participants have copyright on any data produced by them. The researcher however has copyright on any analysis and materials she produces.

The approval from the Ethics Committee was obtained before launching into data collection with the participants.

4.4.9 Conclusion

This research design is guided by the interpretive paradigm with its ontological and epistemological underpinnings. The experiences of writers and teachers during the development and implementation of a new physics curriculum are seen as embedded within a sociocultural framework. The qualitative inquiry was chosen as it approaches the research questions (see Chapter 3) in a way that involves in-depth exploration of human experiences of teachers as the insiders in a curriculum development and a curriculum implementation process. These experiences were explored using appropriate research methods to represent an interpretive ontology that regards experiences and ideas as being constructed by the participants in a social, cultural and historical context. The epistemological stance of the interpretive paradigm is that these experiences can be identified and analysed by exploring the insiders' views on the situation being studied through the discourse of the interview and of member checks.

The methods chosen and the protocols followed incorporated the suggestions in the literature on qualitative inquiry for making research trustworthy and consistent. Focused interviews were used to collect data with some guidance from document analysis especially *Physics in the New Zealand Curriculum*. Ethical considerations were followed diligently to ensure participants' rights and safety. The trustworthiness of the data collected was ensured by the following conditions: length of study (three years), the multiple interviews with the same participants, having multiple participants

who were experiencing a similar situation of curriculum change, returning interview transcripts for confirmation, clarification and further explanation (respondent validation or member checks), and the researcher being from the same community of practice as the participants ensuring some degree of shared meanings. The three interviews, before, during and after the first year of implementation of the new physics curriculum, explored the consistency of the teachers' views over time and noted the changes that have occurred over that period.

The following four chapters will 'crunch' the data and display it in a manner that leads to specific conclusions (Miles & Huberman, 1984). The chapters 'display' the voices of the three writers and ten teachers as they describe their experiences in the development and implementation of a new physics curriculum. Chapters 5 and 6 provide in-depth descriptions and analyses of the curriculum document development process from the viewpoints of the three writers. Chapter 7 presents case studies of two physics teachers interacting with *Physics in the New Zealand Curriculum* and working towards implementing it in their physics classrooms in the first year of mandated implementation. Chapter 8 summarises the comments from all the ten physics teachers interacting with the new physics curriculum document and implementing it in their schools. Chapter 9 identifies and discusses the emergent issues from the data with regard to the barriers and supports for the implementation of the new physics curriculum for these ten teachers.

Chapter 5 ➤ Writing the Curriculum Document: Writers' Views

5.1 Introduction

In order to understand a process of curriculum change, the objectives of those initiating the change need to be considered. A relatively small change in the classroom curriculum can be considered a successful case of curriculum change if that small change is the objective of the new curriculum initiative. A profound change in the curriculum, in evidence in the classroom, may be in directions that were unintended by the curriculum initiative and thus the change may be seen as problematic. This chapter will elucidate the intentions of the curriculum initiative documented in *Physics in the New Zealand Curriculum* from the points of view of the writers of the new physics curriculum document.

Physics in the New Zealand Curriculum was developed in a tight time frame and under tight constraints. The Ministry of Education had commissioned the writing of *Science in the New Zealand Curriculum* in the wake of nationwide school curriculum reforms. A new contract was set up for writing a physics curriculum document when it became clear that the Minister expected individual curricula for the different science subjects – physics, chemistry and biology. The contract was very definite in specifying that the three separate science curricula were to be off-shoots of *Science in the New Zealand Curriculum* and so needed to be written along similar lines and have a similar structure. Thus section headings in the proposed physics document were already in the contract such as levels, achievement objectives, sample learning contexts, possible learning experiences, assessment examples, and investigative skills. Additionally, the writers were required to provide a rationale for physics education and suggest approaches to teaching and learning in physics. A summary of the two contracts (draft and final) for writing the physics curriculum document is given in Appendix D.

To understand the background to the writing of *Physics in the New Zealand Curriculum*, the intended directions of the curriculum change, and the writing process

itself, the three writers of the curriculum document were interviewed. This chapter presents some of the data from those interviews. It begins with section 5.2 which provides the writers' descriptions of how the writing process was carried out. Section 5.3 outlines the major influences on the curriculum document as described by the writers. Section 5.4 considers the statements of the writers on the main changes that they wanted to achieve with the writing of *Physics in the New Zealand Curriculum*. The writers' comments on the major issues and debates that they had to work through in developing the curriculum are described in Chapter 6 under the general headings of political issues, writing process issues, and implementation issues.

The setting out of Chapter 5 is intended to provide a rich description of the development of the curriculum document. As much as possible, the writers' own words are used in the chapter. The account is intended to convey the writers' perception of the curriculum that they have developed. It is important to point out, of course, that these are the writers' perspectives and these may not be shared by the Ministry or other stakeholders. Later, Chapter 10 will consider the writers' descriptions of the development of *Physics in the New Zealand Curriculum* through the lens of a theoretical framework.

5.2 The Process of Writing the Curriculum Document

5.2.1 The writing team

When the contract for writing *Physics in the New Zealand Curriculum* was advertised in the Education Gazette, Writer 1 felt that he had an idea of what it entailed as he had contact with the chief contractor for the Science document and also he felt that he had the experience and interest to do it. He approached two people whom he had worked well with in the past and together they registered their interest in the writing contract. For him, being in a College of Education made administration of the contract easy as the contract was between the Ministry of Education and the College of Education.

The team that Writer 1 brought together to develop *Physics in the New Zealand Curriculum* reported that they had developed good working, intellectual and emotional relationships:

We knew each other and it was me that approached those other two and quite quickly we thought we'd give it a go; we didn't realise just how much work it was going to be, but we got on really well. There were no nasty arguments or anything; there were some debates where we didn't agree, but nothing nasty; it was amazing. (Writer 1)

The value that they placed upon their teaming was highlighted by the sense of missing each other that they experienced at the end of the contracts:

So those kinds of things were discussed and shared with each other. We were emotionally quite, not lonely, but missed each other at the end of these two contracts. It was really interesting. (Writer 1)

...we all came with different experiences and we all came with different beliefs and ideas and together we learnt a heck of a lot from each other. Oh it was so wonderful; I really miss the sessions we used to have. We learnt so much from each other about teaching and learning. (Writer 2)

5.2.2 The contract and constraints on the nature of the document

The physics document had to fit in with the existing science curriculum document because the physics, chemistry and biology documents were add-ons after the Minister indicated that he expected separate senior science statements. Originally the science curriculum document was intended to incorporate the specialist senior subjects:

So they (the Ministry) had to get on very quickly and organise the writing of those curricula. (Writer 1)

...one of the impressions that we got quite strongly in our dealings with the Ministry was, this was initially in the early stages of it, that our document was being judged on how closely it corresponded to the science one. (Writer 3)

Writer 1 was on the reference group for the physics part of the science curriculum document. The physics strand in the science document concentrated largely on skills and processes of doing physics rather than on content topics. That was left to schools to decide. The physics writers were aware of the debates and criticisms generated by doing this and so when it came to the physics document they wanted to be "adventurous ... but still have our feet very firmly on the ground" (Writer 1).

They were excited at the prospect of writing a curriculum and not just another prescription because physics did not previously have a written curriculum for secondary schools in New Zealand. In the past, the physics curriculum was based on examination prescriptions and some degree of custom and practice:

I jumped at the chance that it was to do with us actually writing a curriculum rather than a prescription. (Writer 1)

Basically just to re-vamp the physics curriculum and what was taught in physics and decide what should be there and actually write a curriculum, not a prescription, so write a document that teachers would use to design their learning programme from, not something just to pass an exam. (Writer 2)

However their writing brief made it clear to them that what they were writing was not a curriculum but a statement of the physics curriculum framework:

What we were writing was not a curriculum but a curriculum statement. ... By the curriculum statement I think what they were trying to do was to abstract from the curriculum what its underlying agenda was, what its aims and objectives were without having to couch them in terms of any content. (Writer 3)

5.2.3 Guidelines given in the Ministry's writing brief

The writers were given a writing brief by the Ministry outlining the shape of the document to be written. These guidelines included the requirements for brief statements to describe achievement levels in terms of objectives and for examples of learning experiences and assessments. Writer 1 felt that the brief was politically driven (this is further discussed in section 6.2.1) and had constraints of what was allowed to be included at each level and also the measurability of the objectives:

We have these constraints that the general shape of the curriculum was set for us that you had Levels 6, 7 and 8, and they had to be increasing in sophistication that you couldn't repeat stuff at each level, they were to be written as Achievement Objectives that is at the end of the course of study they should be able to do this so that ideally they should be measurable. So those things were all given to us politically. (Writer 1)

Writer 3 emphasised the point that the structure of the curriculum document that they had to write was decided for them. There were strict guidelines to be adhered to in developing the curriculum document:

There was a specific set of guidelines, set of terms of reference which we had to abide by which was given to us in writing from the Ministry. The main feature of which was a statement which basically defined the structure of the whole document, saying that it essentially had to consist of a set of statements, of brief statements, so they were very few in number. One set of statements at each of Levels 6, 7 and 8, and that was to be followed by examples of learning experiences, and that had to be followed by examples of assessment practices. ...The basic structure of it was pre-defined. (Writer 3)

5.2.4 Time frames for the writing

The first writing contract was signed at end of 1992. The writers worked through four drafts to August and in October 1993, the draft document was published and circulated. Submissions were made by Christmas 1993. The submissions were collated and a writing brief was produced in April 1994 for the final curriculum document. The three writers applied for it and won the contract to do the final curriculum document. In that contract, they did three drafts before the final document was produced in October 1994:

In fact our very first draft, what happened was the published draft went around the country and circulated for six months or so or whatever it was and all the feedback came back to Wellington and was analysed in Wellington and then they prepared a brief for the writing of the final document and our reaction to that brief was we finally got a brief to redo the very first document that we wrote. (Writer 3)

The first draft curriculum document was written over a ten-week period during many three-hour meetings. In these meetings much discussion took place and one of the outcomes was reaching a consensus about their philosophies of physics education:

The real huge push was done over one of the Christmas holidays where we basically nussed the whole thing out over that eight or ten week period one Christmas and we had countless three hour meetings just talking and talking and reading and talking. And I think we had sorted our own philosophy out in the course of that ten week period and we were really lucky as a working group in that our philosophies just gelled. (Writer 3)

5.2.5 The review process

There were cycles of writing; they had to produce four drafts before arriving at the draft document that was published for circulation. A number of groups reviewed each draft document, mainly the Review Committee and the Reference Group. The writers

were required to form a reference group which included some names given to them of people who had registered interest to write the physics curriculum but were not chosen.

People or groups other than the writers who were involved in the development of the document were the Review Committee, Policy Advisory Group of the Ministry, Ministry liaison person (also called the Curriculum Facilitator), Minister, writers' own reference group of 12 people, and significant others such as university lecturers, teacher colleagues, and the Institute of Physics. There were also people overseas, who had a high profile in physics education, who were invited to comment on the physics curriculum. There was another group in the Ministry of Education that, from an administrative financial point of view, checked that they were keeping on target. "That was more of an auditing situation but very much removed from the actual curriculum itself" (Writer 1). The layers and networking in the case of *Physics in the New Zealand Curriculum* were extensive (see Figure 4) but not as wide as for the science curriculum document.

The writers were told that there would be an advisory group, the Review Committee, from the Ministry. This was an augmented sub-committee of the Policy Advisory Group for the science curriculum made up of some people from that group and others more relevant to physics, from the University and the NZQA:

...there were people on the Review Committee who were not on the Policy Advisory Group. The Policy Advisory Group was a Ministerial thing set up to advise on science in general and covered all three sciences and that group was set up to advise the Minister. This group, this review group was set up to report to the Ministry. (Writer 3)

The Review Committee was given each draft that the writers produced in each cycle of writing and looked over it from an overall perspective of science and the curriculum framework. They wrote their comments that were conveyed to the writers through an intermediary, a Ministry liaison person. However there was some filtering of the comments of the Review Committee by the Ministry as the Ministry saw it as its responsibility to produce a curriculum that the Minister of Education would approve.

The Ministry liaison person was the Curriculum Facilitator and he presented the writers with a brief on what was to be in the physics curriculum document. He was the link between the writers and the Ministry's Policy Advisory Group and the Review Committee. The writers wrote the drafts and this was given to the Curriculum Facilitator who handed it to the Review Committee that met and gave written feedback on the drafts which was then given to the writers through the intermediary of the Curriculum Facilitator. Such a roundabout method of review left much confusion in its wake and so in the later drafts, the writers were able to communicate directly with the Review Committee.

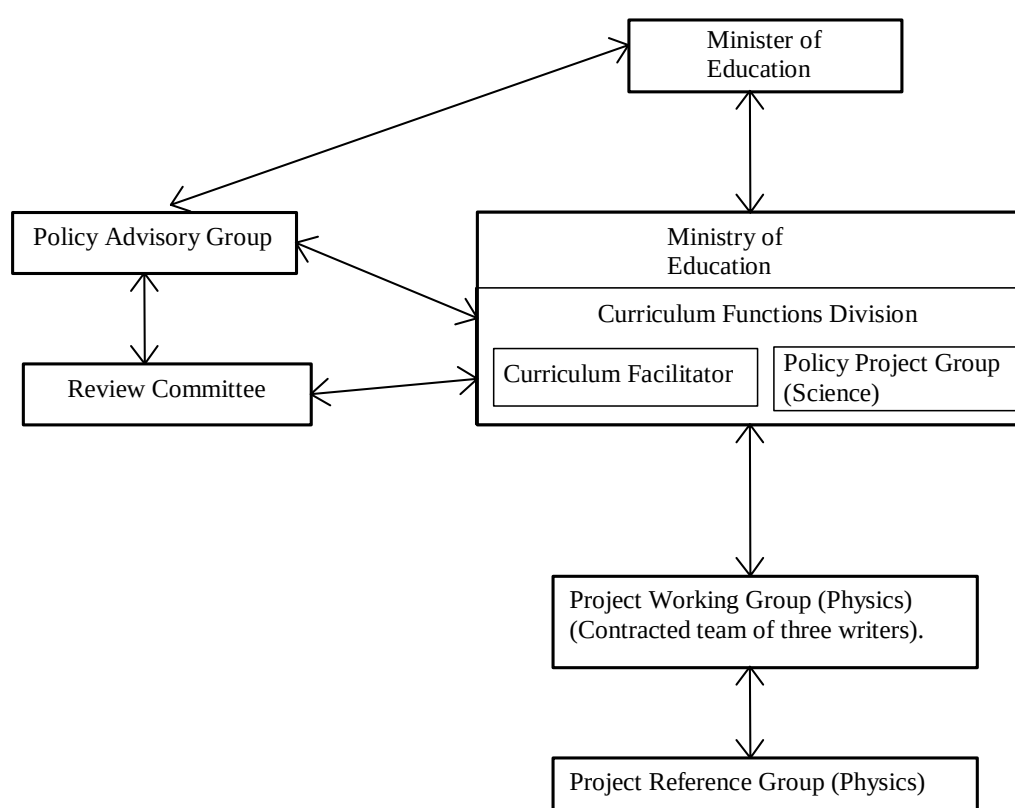


Figure 4: Consultative network involved in guiding the writing of *Physics in the New Zealand Curriculum*

The writers found this method of review to be not a satisfactory situation as they would have liked to have met the Review Committee earlier to explain what was new and their thinking about the latest draft:

We felt that the key communication would have been better that way ... because we were always trying to second guess everything ... (Writer 1)

There were certain milestones that we had to meet, the deadlines in terms of time and how far we had to be. It was our advisory group that was quite restrictive in a way because we would write a milestone and give it to them, they would send it back with comments, and then we would then take those comments and then carry on from there. That was quite restricting in a way because the information we got from them was from an intermediary, via minutes from that meeting and it wasn't until very late on in the project that (Writer 1) managed to get to one of those meetings, so we could get first hand what was happening... (Writer 2)

The reference group of twelve people got together for two one-day meetings with the writers after the second and fourth drafts in the production of the published draft *Physics in the New Zealand Curriculum*. They were flown in from all over New Zealand. They all had the draft document and commented on it; what they liked about it, what they wanted changed and how they thought it was going. The writers took brief notes as this was going on:

We had a teachers' group, a reference group which met a couple of times and we showed what we had done and got their input. We also sent information to them and asked for comments which we took into consideration when we wrote, doing our work.... Yes it was national and it was a variety of people from schools, AIT, universities, polytechnics and industry, there were a few people from industry on it. (Writer 2)

The writers relied heavily on the feedback from their reference group:

We've also had a reference group that we relied heavily on and they have been giving us feedback all the way through. So we didn't find that there's a big change in direction. (Writer 1)

Despite the Ministry brief and input from various sources, the writers felt that the document did end up as their group compilation:

We three had the greatest input and were able to have quite a free range so I think this final curriculum is very much stamped with our three philosophies. (Writer1)

We just wrote the draft the way we wanted and then attached explanations saying why we still believed that this was a better way of doing it. Sometimes those were accepted and sometimes they weren't. (Writer 3)

The writing of the physics curriculum document underwent a stringent review process. Each draft was scrutinised especially by the Review Committee and the Reference Group, and their comments were taken into account in writing the

subsequent drafts and the final document. Despite some conditions that were not very acceptable to the writers, they felt satisfied with the outcome as they felt that they managed to infuse their own philosophy into the document.

5.2.6 The actual writing process

On behalf of the Ministry, the Ministry liaison person, defined what needed to be included, for example, the aspects to 'Approaches to teaching and learning'. The communication with the Ministry liaison person was through phone calls, faxes, mail and through face-to-face meetings when he visited the writers.

There were some time slippages, sometimes up to a month, because the writers did not receive in writing the minutes of the Review Committee. They attributed that to the workload of the Ministry liaison person because he was servicing a dozen or so different curriculum contracts.

The writers had completed four drafts prior to the final draft document being produced. When the same writers were awarded the contract for the final document, they got together another group of people for their Reference Group. Unlike for the Reference Group when doing the initial drafts, the writers did not fly them in for any meetings; instead all communication was conducted in written form. The Reference Group was paid a small amount of money for their written replies to the drafts.

In writing *Physics in the New Zealand Curriculum*, the writers found that every single word had to be considered, redrafted, and checked; especially in the introduction and the objectives, so that the right flavour or meaning was conveyed by the paragraphs. Certain paragraphs had to deal with content, some had to deal with investigations, some had to deal with society and some had to deal with further education in physics. They also had to think of the physical layout of the document so that teachers would not have to be turning pages all the time.

Thus, there was much discussion and the writing process was not always a smooth ride; many hours were spent over a few words and sometimes they came right back to where they had started from in their ideas:

It was largely that talking about things and one or two classic times we might have changed three or four words after three hours. We found sometimes that we completely changed back again. (Writer 1)

Writing the Introduction

To the writers, the introduction section in the curriculum document was taken very seriously as the writers felt that it set a frame of reference for the reader to proceed further in their understanding of the document:

But the introduction as I said before is a very carefully written thing that's been gone over many times to give the right nuances of meaning, to push people's bells you know that they should be thinking of numeracy and further learning and gender and culture and you know all these key words come out in it. (Writer 1)

The introduction also contained a paragraph alluding to the 'physical science for all' idea. This was included because it related to the 'science for all' idea in the science curriculum document. It also included the idea that the physics document was an add-on to the science document:

These are kind of extra limbs stuck on to the science document. So right at the start we say "you have to read this in conjunction ... with those ones" (sections in the science document). In other words we are saying that this is the extra stuff to what's said there. (Writer 1)

Writing the Achievement Objectives

To arrive at the achievement objectives, the writers looked at what they saw as important in teaching physics or in what students learnt in physics. The writers described themselves as being both academic and practical in their approach to physics education, and their teaching covered aspects of theoretical and practical learning. The classroom experiences of two of the writers who were also secondary school teachers at that time were used to confirm the objectives that were regarded as important in the learning of physics:

So we had quite a lot of discussions about what's important, especially early on but they still carried on. We found we developed a very strong bond, the three of us, we worked well together, we would naturally you know talk for half an hour on the phone and we still do in those ways. And as the year progressed we'd also talk about what, in the other two cases because they were practising teachers, what was happening in their classrooms and what either

consolidated what we thought about physics or what came out as exceptions to what we thought. (Writer 1)

For the very first draft, the writers tried to write an achievement objective for every bit of physics content and soon got fifty objectives for two topics of the year's work. They realised that it was not a good way to proceed, especially from the feedback of the Review Committee, and so they changed and tied content loosely to the objectives with the aim of stimulating debate among the teachers. "We had always planned to put content in, specify content, but in the draft we made things very flexible, teachers could select content" (Writer 1). So the writers actually wanted feedback from the published draft as to what physics topics teachers felt were important to teach:

I might say that what's in the final one is still less than that what was in our very first draft. We put more content, more specified content, in our very first draft but it got knocked out of it. I mean the first draft that you're looking at, the draft version that you're looking at was in fact about our fourth draft. So we have done about three drafts before one was ever printed off and published around the country. And that was reviewed. Each of those drafts was reviewed by reference groups and various committees. The content has been knocked out of it during that process. (Writer 3)

The writers viewed the achievement objectives as being centred round understanding the concepts of physics, having investigative skills, and acknowledging the role of physics in society:

But we realised, yea, we sat down and talked, "what are the key things that we expect to come out of a learning programme of physics? What should students come out with?" And we felt that they should come out with concepts because without it then we can't do anything; they should have some investigative skills and they should have some appreciation of where physics fits in now, where it fitted in the past and where it is going in the future. (Writer 2)

Writer 2 said that the ideas by the writers about the aims and objectives of the curriculum converged when they considered each other's points of view in their discussions. This was acknowledged to be a time consuming process:

No I think we talked through it all and came up with it ourselves. Because initially we started just discussing openly, not reading heaps and heaps, but actually just discussing our ideas, our own beliefs, and what we thought physics was, and what should be taught and what should kids learn. ...I felt so, we often had very different ones but it was often because we haven't considered that point of view, so we listen to it all and then, oh yea I think that should be in, so it will go in....Take some of this content, I think I will change

a bit of the content; I like this, I might change the wording of some of these, but I like the objectives or the aims, I like the aims. We spent a lot of time working on these. (Writer 2)

Writer 3 described the process by which the writers arrived at the six statements comprising the aims and objectives of the new physics curriculum. The process included listing their own thoughts about physics, reading up on overseas physics curricula, and reviewing critiques on curricula by particular people:

What they are are a condensation of all of the things. We just wrote down a big long list of what we thought would be learning of worth in physics. We read a lot of articles, (Writer 1) just kept on finding more and more and more, a lot of philosophical stuff from educational writers in Britain and America and Australia, a lot of people who had different angles on what should be in or out of curricula. We got hold of various curricula from around the world, physics ones. We looked to see what was commonly included internationally in different curricula. We looked at things like the science, technology and society movement in Britain. We looked at technology curricula and we got a pretty comprehensive grasp of what anyone else anywhere else was doing with their curriculum. We looked at people who were writing critiques of curricula saying what was inadequate about them. We listened to people like what's his name Matthews, Michael Matthews and his arguments of the worth of historical content in curricula and philosophical content in curricula. And we put all that together and it came out as six statements. (Writer 3)

Writing the curriculum content

The writers believed that the content of physics was inextricably tied up with achievement in studying physics. However, the science curriculum document was specified not to include content. For physics, the writers included content as suggestions in the drafts with the use of words such as 'suitable for developing', and 'could include', implying that there was nothing definite with regards to content. When the draft *Physics in the New Zealand Curriculum* was published, there was an opportunity for people to make submissions and give feedback on the draft curriculum document. There was not a lot of feedback on the draft document and comments from only 28 organisations or people were received nationally. There were 24 comments specific to physics only. The general consensus was that content needed to be specified and so the writers took that as a mandate that they had to write some content:

There weren't as many as what we thought there would be 'cos that also included some single people as well as organisations. It practically affected us

from the point of view that somebody collated them together, picked out all the general similar themes and a few of the divergent ones, presented it to the policy advisory group who, together with the Ministry, worked out a writing brief for the development of the final version. So they made some policy decisions: “you will need to list a set of content a bit more specifically than previously”. (Writer 1)

In terms of the content to be included, the writers resorted to existing custom and practice with minimal changes of what was in the current examination prescriptions:

So in the same way that custom and practice need to be seen to be behind all this anyway; so where we have a set of content here, we are specifying that content with the idea that the previous prescriptions have specified that content. ... not driven a huge amount by what's gone on ahead before in physics, but still wanting to retain the good bits of the previous physics prescription. (Writer 1)

They felt that the fundamental principles of physics were well encompassed in the content of the existing prescriptions:

Well again it was the fact that there is a basic core of physics that is fairly well laid down. And we looked at all these old prescriptions and really decided what we felt should go in. We didn't want to change it too much because our aim was to change the approach, our objective was to have students coming out of physics with some understanding and appreciation of the subject. And also these are fundamental things that students need in order to develop further in physics. (Writer 2)

Writing the Possible Learning Experiences section

The Ministry brief indicated that the writers provide Sample Learning Contexts related to the Achievement Objectives and a Possible Learning Experiences section. These and other headings were derived from the previous contract for the science curriculum document. In choosing examples under these headings, the writers derived them from their own experiences and from their readings. They also resorted to ideas from the reference group members and also from other colleagues:

A lot of them are things that we've done ourselves over the years. Others were when we circulated the document out to our reference groups, we often said can you think of any others, and they sent other ones back in. (Writer 1) had a wide sort of circle of colleagues whom he went and visited in schools and had seen a lot of what was happening. All of us were familiar with the whole range of textbooks and books on physics and so a lot of my ideas would have come

off that bookshelf. And each of us would have our library of books which we would have been able to draw on for those ideas. (Writer 3)

Writing the Assessment Examples section

When writing the final curriculum, the writers were told that assessment in the curriculum would be dealt with later by others, meaning the New Zealand Qualifications Authority (NZQA). This posed a dilemma for the writers as they were worried that some of the aims may not be easily measurable:

When we were wanting to find out where our job began and ended, we were told “all you have to do is identify and list, or identify and describe learning of worth, things that you think will be worth putting into a physics curriculum”. And we could come up with all sorts of stuff on maybe the nature of science or the philosophy of physics. And then we could ask ourselves the question “but I wonder how you go about assessing this?”, and when we approach Ministry with this question they would say, “Look, don’t you even worry about that question because the task of assessment would be carried out by someone who shall come after you.” (Writer 3)

In the end the final document contained a rich set of assessment examples. The writers considered that the assessment examples given in the document were there mainly to illustrate the achievement objectives that otherwise had to be understood through a few condensed sentences:

That’s why we ended up doing lots and lots of examples because we realised that in fact the only thing in that whole document that was making it clear what we meant was the assessment examples. (Writer 3)

Writing the Developing Scientific Investigative Skills and Attitudes section

The three science curricula, physics, chemistry and biology, had to incorporate a section on investigative skills - this was a directive by the Ministry. The writers of the three science curricula had two joint meetings over the two years it took to develop the draft and the final document. In the drafts, the nature of how the investigative skills were to be included changed significantly and the final draft had achievement objectives for investigative skills and attitudes going all the way from Levels 1 to 8 which were taken from the science curriculum document. In the final document it was changed to a set of achievement objectives going from Levels 5 to 8:

We used the document (Science in the New Zealand Curriculum) to begin with and we spent time looking through it and we used the investigative skills

section and just picked out the ones that applied to physics. In fact all the documents have done that and again we were actually directed to do that. (Writer 2)

Yes, oh we were told to do this too, basically take the science stuff and change the context to physics. (Writer 3)

An interesting comment made by Writer 1 was that the writers did not feel that they owned the investigating skills section and were quite dismissive of its place in the new curriculum:

This was largely taken from the science curriculum and because we didn't have a lot to do with that we tend not to think of it as part of the physics curriculum. (Writer 1)

The physics writers' main input in outlining the investigative skills was in rewriting the possible learning experiences for the skills with physics examples. One other input included through a directive from the Ministry was the writing of a statement on safety. The three science curricula development teams met and came up with similar safety statements.

5.2.7 Summary

The writing team that Writer 1 brought together to develop *Physics in the National Curriculum* formed a working group with strong relationships. They were enthusiastic about producing the first written physics curriculum for secondary schools in New Zealand. The writers worked with the framework of a contract with a writing brief provided by the Ministry outlining the document to be written.

The draft curriculum document was published in October 1993. Following that, submissions on the curriculum were collated and a second contract with a writing brief was produced by the Ministry in April 1994. The same three writers applied for and won the second contract to write the final *Physics in the New Zealand Curriculum* document. They again were helped by the Project Reference Group (a different group of people chosen by the writers for the second contract) and the Review Committee set up by the Ministry that provided the writers with written comments (filtered by the Ministry).

By the publication of the final curriculum document, the writers had completed their work of developing a document that they believed could support a different culture of physics teaching and learning in the classroom. The key components of their contract included the development of a document that set national directions for school physics that were consistent with the parent document *Science in the New Zealand Curriculum*. They needed to develop a document that reflected and built on current understandings in physics and science education and incorporated the best contemporary physics and science teaching practice. They were also directed to address barriers that were preventing all students from achieving personal excellence. Under these Ministry guidelines and based upon their experiences as physics educators, the writers had made significant inputs into the development of the achievement objectives, had specified content and had included a section on investigative skills. They had also provided a range of examples of contexts for learning physics and for assessing students' knowledge within the framework of the achievement objectives. Fundamental to the evolution of the final curriculum document had been a long and reflective process of making numerous decisions involving the meaning and function of almost every word in the final document.

5.3 Influences on the Curriculum Document

The comments from the writers of *Physics in the New Zealand Curriculum* highlighted a number of influences that impacted on what was written in the physics curriculum document. The main influences acknowledged by them were from the Ministry of Education in terms of the Ministry's contract and writing brief, and reviews from its Review Committee; the *Science in the New Zealand Curriculum* document; the writers' philosophies and experiences; the feedback from the Reference Group and submissions after the draft was circulated nationally. The influences from the Institute of Physics; existing custom and practice; and ideas from significant individuals such as physics education experts were also acknowledged. The writers' specific views about these influences are given in sections 5.3.1 to 5.3.7 below.

5.3.1 The Ministry's influence

In the 1990s, the national curriculum for schools in New Zealand underwent a complete revision and the different school subjects were then brought into line with

the national curriculum guidelines. The curriculum revision was called *Achievement Initiatives* and was the brainchild of the then Minister of Education, Lockwood Smith. All three writers felt that the new physics curriculum that they had to write was politically driven:

We saw it as part of the total revamp of planning, updating of the curriculum framework that Lockwood Smith was putting into practice. (Writer 1)

Oh I think this is very politically driven. We felt a bit of resistance about that and I would say a lot of it is very politically driven. (Writer 2)

But definitely the Ministry's sort of new age political thinking would be the biggest single factor. (Writer 3)

The brief that was provided by the Ministry was based on the previous contract to write the *Science in the New Zealand Curriculum*. The physics curriculum document was seen as an addendum to the science curriculum document:

Well this was always meant to be part of the science document, these were addendas to it. That was how they were; we were briefed that that would be that. (Writer 3)

The curriculum document had to have levels and achievement objectives in each level that were measurable. The writers were asked to provide 'Sample learning contexts'; 'Possible learning experiences' that were examples to illustrate the Achievement Objectives; and Assessment Examples for each Achievement Objective. There were constraints on what they could write that frustrated the writers:

There were constrictions on the verbs we use there, and there was also a general stupid thing that was imposed on us that each of those performance objectives was meant to be measurable. So there was a behaviourist constraint imposed in the brief from the Ministry. Although that was a tension, that was a hell of a tension, because how do you make it sufficiently general to cover the whole syllabus in six statements and yet sufficiently specific to be measurable. It's not neo-behaviourist, it's just crap. (Writer 3)

The writers had to write within the guidelines of the brief and their drafts were reviewed by the Review Committee with those in mind, their adherence to the principles of the *National Curriculum Framework* and their alignment to *Science in the New Zealand Curriculum*. The writers considered that the Review Committee had the biggest influence on what they wrote in the physics curriculum document:

The review group, because out of their comments would come the next brief from the Ministry which would detail how we had to change it. (Writer 3)

That came back, there was some sort of agenda I think driving the way the Ministry wanted the document to look and they would assert these constraints on it in their feedback and rebriefings ... when they saw they violated any of these 'ministerial dogmas'. (Writer 3)

The Ministry's control is illustrated by the following comments where sections were included in the final curriculum document without reference to the writers:

The advisory group themselves, looking at how we developed on from the science curriculum and the curriculum framework, introduced without our knowing right at the end about the development of essential skills. (Writer 1).

We didn't write that, that was shoved in by someone else, all this skill stuff, all that stuff; that rest of the document from there on wasn't even written by us, just appeared on it. (Writer 3)

The interactions of the writers with the feedback from the Ministry and its Review Committee are highlighted in the following comments by the writers. There is a sense of loss of control by the writers in these interactions:

There were a few other things we were told by the Ministry as time went on, such as safety on page 10 ... we were told to bring that in. The advisory group also suggested that we stressed the importance of the language of physics and the place of mathematics was at one stage seen as the language of physics, but now we got them in as separately. And then the development of the essential skills on page 8, we had nothing to do with. It appeared between us sending in the final revision and this thing being printed. And that was the advisory group that decided to put that in and that's taken from the science curriculum, the main green document. (Writer 1)

We would have gone through it all, and taken the suggestions, particularly from the Ministry group, you see the Ministry group, they don't make suggestions, well they do, but basically we have to take notice of what they say. (Writer 2)

Writer 3 expressed his frustration at the constraining influences of the Ministry in the writing of the curriculum:

That was the most stupid hassle we had with the Ministry time over time. They refused to allow us to make any quantitative statements about the weightings of those things. ... We wrote that it was to be no more than about ten percent and had it crossed out because numbers were evil. ... the Ministry insisted that it had to be written that way. ... There was a hell of a lot of outside influence on the construction of this thing. (Writer 3)

However, the comments of Writer 3 indicate that in spite of the Ministry imposed constraints, the writers eventually developed a document that they considered had its own thrust:

Initially quite constrained because we were told that this document was an extension of the science curriculum and it had to be in the same style and spirit but eventually it took on a life of its own and they forgot about enforcing that. (Writer 3)

5.3.2 The influence of the writers' philosophies and experiences

While acknowledging the Ministry's strong influence on the physics curriculum document in relation to the terms and conditions of the writing brief and the review feedback, the writers felt that they had managed to infuse their vision of a physics curriculum for schools in New Zealand. The writers' backgrounds, their experiences and philosophies were seen by them to have had great influence on what they wrote in the physics curriculum document:

It did end up a group compilation. We three had the greatest input and were able to have quite a free range so I think this final curriculum is very much stamped with our three philosophies. (Writer 1)

Writer 1 emphasised the need for students to have "an affection" or a liking for physics:

So we were trying to inject some kind of life into the physics curriculum and we've squeezed in a few ideas that in one case I managed to get a phrase that I particularly wanted in this about how they have an affection for physics. (Writer 1)

The writers came from a range of teaching backgrounds but they held a common passion for teaching physics with a focus on students:

So we had a wide range of experiences of co-ed, of single sex, academic, non-academic side of things. But it was largely a passion for teaching physics, for switching kids on to thinking, getting them able and confident in their investigating, and to look at things that happen to them in everyday life from the physics point of view as well as normal; and having a keen sense of what do kids like, what that they don't like. So that's where we came from... (Writer 1)

He felt too that the teaching of physics needs to be based on concepts, principles and models, and on the applications of those in real life:

We saw that first strand of concepts, principles and models as forming the backbone of physics, that's in many ways the lasting thing that we would expect the students to understand and further than that to apply those concepts to explain actual physical phenomena, systems and devices. You can't really do physics without having some connection to real life physics, whether it is natural or whether it is human-made, so that's why we got systems and devices here too. (Writer 1)

Writer 2 mentioned the philosophical and societal issues associated with physics as being something that she had fought for to be included in the new curriculum:

I think that this is really important, the nature of it, the nature of what is physics, to be able to talk about those kind of things, the philosophical issues and the lives of scientists. (Writer 2)

This one, I don't know whether I suggested it but I fought very hard for that (the nature of physics in Objective 2). ... This is it "physics is a box of tools used to construct the true picture of the universe". (Writer 2)

Another concern for Writer 2 was that the document should not be over-prescriptive for teachers as they have their own teaching styles, and the needs of the students they have may vary from one year to the next:

I am not open-ended, I don't agree with that. I mean I like to know what I have got to do. But I don't want to be told how I should do it. I know I've got to cover Newton's Laws because it says so here, for example. ... I need to know some boundaries, but no one should tell me what aspect of it I should do and no one should tell me how I should do it, because that varies from year to year because it depends on what's in front of you, or your own particular way of doing things. (Writer 2)

Writer 3 felt that he could identify his philosophy and why he held it. He emphasised the need for a sound operational knowledge of physics grounded in concepts, principles and models:

One of the basic core axioms I suppose was that there was a need for people to actually have, for students to actually emerge from a school course in physics with a sound operational understanding of the subject of physics and not some namby pamby learning about physics, or pretending to know something about physics or drawing pictures about physics or fantasies about what physicists do. We wanted it to be the actual subject and so that's why it has shown up in the basic learning objectives that they will be able to apply concepts,

principles and models. We wanted them to be able to use those concepts to actually solve problems. (Writer 3)

The writers' own experiences of teaching physics impacted greatly on what they wrote. They described the influence of their experiences as members of the community of practice of physics teachers:

I supposed it was biased because I mean a lot of it is from your own experience isn't it and you get to appreciate what is interesting for students and what is not and why a particular way you teach something is interesting and why it is not. ...I mean kids are interested when they see the use of something and I know girls are particularly, but everyone is, isn't it? (Writer 2)

So we knew that there were quite strong feelings amongst physics teachers about certain pet subject areas. (Writer 1)

Their classroom teaching experiences formed the basis of much of what was written in the curriculum document, and so they felt that the curriculum was designed for the physics classroom:

Certainly from my point of view the main thing has been on the philosophy of it and the content of it. What we are trying to do when we were, we would often just talk about our experience of teaching physics, what we saw as important in the classroom, they were all classroom based visualisations so to speak. So everything was rooted and grounded in classroom physics teaching. (Writer 1)

5.3.3 The influence of physics education researchers

Apart from the writers' own experiences and philosophies, they explored ideas from significant individuals and took on ideas that they felt were useful for the physics curriculum. For example, Writer 1 mentioned the work of Lillian McDermott in USA and of the Learning in Science Project (LISP) research in New Zealand:

We've done some reading up of conceptual development in models such as by Lillian McDermott ... in University of Washington. (Writer 1)

LISP had a lot to do with that too, especially, I used quite heavily the electricity teaching unit that was produced at Waikato where the students are encouraged to make up their own models of electric current and to critically examine those; what scientific things did they predict or simulate accurately. (Writer 1)

Writer 3 also acknowledged the influence of Joan Solomon and of a talk by a Hungarian physicist he had attended at an Institute of Physics conference. Their ideas such as ‘teacher as a persuader’ and ‘students working at the boundary of their own understanding’ were incorporated into the curriculum document:

... one of the words that Joan Solomon used to describe the teacher’s role was that of a persuader and I think that was one of the things that was a lot of the time on the back of our minds when we were thinking of what the teacher’s role was. (Writer 3)

‘Working at the boundary of your own understanding’, that idea came from a brilliant brilliant physicist, a Hungarian guy. He came over and delivered a fantastic lecture at the New Zealand Institute of Physics Conference in Palmerston North in 1991 which was all about the purpose of physics education. It was just amazing, looking back on it, it was just amazing. (Writer 3)

5.3.4 The influence of the writers’ reference group

The writers had access to two reference groups for feedback: one for the draft document and another for the final document. For the draft document, a Reference Group with 12 members was set up by the writers; eight of them were physics teachers in secondary schools. There were also professional physicists: two from universities, a woman professional engineer and one person from a polytechnic. The members came from all over New Zealand including rural areas. Some of the reference group members had written textbooks. Some of the group had membership of the Institute of Physics. The writers found feedback from the reference group to be useful:

Yes, well they had the draft and they then said their piece about what they liked about it, what they wanted changed about it, how they thought it was going. ... We’ve had this reference group which had some people who were willing to misinterpret things or who accidentally misinterpret things and we saw ah we’re not quite clear there; they are picking up on something that we hadn’t thought of. ... There was good debate from people. ... We had people from rural areas who took a brief for the rural schools so that we didn’t without thinking impose a lot of city conditions on things. But we certainly did take on some of the details, some of the examples given us by people. (Writer 1)

The writers also sent their drafts to some of their other contacts in the field of physics education who were overseas.

5.3.5 The influence of existing custom and practice

The writers considered the physics curricula of other countries particularly those of Australia, Britain and the USA:

We looked at the Australian ones, we looked at the British new curriculum, ... and we read a bit about the sort of movement that was going on in various countries. (Writer 2)

However they preferred to go with the existing custom and best practice in New Zealand schools:

New Zealand has had a fairly strong tradition of not having a particular textbook, of teachers wanting to do it their own way. You know it's tied in I think with the vestiges of the pioneering situation where we are fiercely not wanting to tie ourselves to American prescriptions or British ones but to use them selectively. (Writer 1)

The more we thought about what was important in physics, the more we came back to the traditional aspects of mechanics, electricity, heat, light, nuclear. (Writer 1)

The writers consciously included what they considered some of the best current practices from the range of experiences of physics teachers such as themselves:

Well some people do these things so they were things that a lot of us did, or have already done (referring to examples). (Writer 2)

This idea of best practice is a good idea and so some of our examples suggested, examples that students could be doing, has this idea of best practice or usefulness. (Writer 1)

Also in terms of existing custom and practice, the writers identified the current examination prescriptions, sometimes referred to as the physics syllabus (traditionally used as the basis for the teaching schemes in many schools), being considered when deciding on the content to be covered by the new curriculum:

Well we took it (exam prescription) and went through all the content and decided what we thought should be in it. (Writer 2)

5.3.6 The influence of submissions on the final draft curriculum

Another important influence on the outcome of the final document was the feedback from the submissions received after the final draft document was circulated to all physics teachers and other interested people nationally. The thrust of the feedback from 28 organisations/individuals indicated that there should be prescribed topics to be taught at each level:

That shift occurred primarily as a result of public opinion and the feedback that was obtained from round the country after the draft was published and discontent with the lack of content that was in the draft. (Writer 3)

The professional body called the Institute of Physics made up of scientists and teachers and other professionals involved with physics were also consulted. As a consequence of the draft curriculum document, they had discussions and made submissions that impacted on the final structure of the physics curriculum document. The Institute of Physics decided to adopt the section on purposes of physics education in the final curriculum document as policy in 1993. The discussions also resulted in the Ministry and writers addressing the issue of including the importance of mathematics as being intrinsic to physics:

We had a fairly significant meeting at the Institute of Physics Conference was it at end of '92? I'll have to look up the dates but it was where the professional physicists and the tertiary physicists looked at what we were doing. They adopted some of the things that we were saying as their policy in education in physics which we incorporated in the front of the final draft but they strongly said that we needed a good Maths in it. And within a week we had written one which came out in the draft and then was re-written a bit more clearly in the final one. So there was an example where the Institute of Physics Conference had quite a significant input both in the confirming way as far as our basic philosophy but in the more directive way saying "look Maths is more than a tool you use, that it is intrinsic in physics". And so we changed the wording to intrinsic; you know you can't separate Maths from physics, and so we got a bit stronger. (Writer 1)

The Institute of Physics was instrumental in exerting pressure on the Ministry to include prescribed content into the final curriculum document:

.... yea, we encouraged them to be a pressure group. We gave them a bit of ammunition so they could rain hell, fire and brimstone down on the Ministry after the draft came out and it worked. Everyone else had just sort of reasonable contributions to make and so did the Institute of Physics; I thought they were pretty reasonable. (Writer 3)

Another outcome from the nationwide consultation of the draft physics curriculum document was the submissions made by the Science Technicians Association. Their concerns about the need for adequate resources and science technician staff were included in the final document. Thus the influences of the different stakeholders were evident in the final document. At times the influences were conflicting and the final curriculum document is an outcome of the interplay of all these influences.

5.3.7 Summary

The writers considered that the biggest influence on the writing of *Physics in the New Zealand Curriculum* was from the Ministry: starting with the writing brief provided and adherence to the set agenda; the feedback from the Review Committee after each draft; and additions to the final document made without reference to the writers. The writers also delineated their own very significant influence through their beliefs and their experiences in the field of Physics Education. There was also a network of consultation and submission that led to the final document. One of the most significant entities in that network was the Institute of Physics. It is evident in the writers' comments that despite the heavy-handed control of the Ministry, the writers felt that the final document was still infused with their own flavours and ideals.

The transcripts dealing with influences demonstrate that the writers were very aware of what would be critical if the new physics curriculum was to lead to change. They thought that it would be important for the curriculum to address the beliefs, attitudes, interpretations and values of the teachers themselves (Fullan, 1991; Goodson, 1994; McGee 1997; Zuga 1992). Yet, discounting the submission of the Institute of Physics (a professional body), submissions by the physics teachers' community of practice on the draft document were sparse. The potential for a "gap" between the curriculum document and existing custom and practice gave rise to issues that will be discussed in the next chapter.

5.4 Main Changes Intended in the New Physics Curriculum

The writers of *Physics in the New Zealand Curriculum* wrote it with change in mind. Although they were aware of the psychological demands of big curriculum changes on teachers, they still wanted to bring about some changes in areas that were of particular value to them:

...essentially what we are aiming for is for effective learning by the kids which I think is fundamentally the best, is the proper thing. But operationally we were also thinking of the existing physics teachers, that it had to be something that they could move to that wasn't too big a jump. (Writer 1)

5.4.1 Intended Change: Emphasising that physics knowledge is embedded in society and culture

One main area of change that the writers agreed on was bringing in the human aspects of physics which involved the nature of physics, historical and philosophical aspects of physics. This was given fair emphasis in the new curriculum document (and not just a fleeting mention as in the previous examination prescriptions) by making it one of the three aims of the new physics curriculum that tied in with an Achievement Objective. In particular, it was written in as Achievement Objective 2 and being an achievement objective also meant that it has to be assessed. This was not usual practice in the existing physics curriculum that was based on examination prescriptions:

... this aspect of physics we've introduced is because of the fact that physics is a human activity and has people that do physics, and so society and culture apply to it too. So for example then we've got 'describe influences of everyday physics based applications on their lives', so things like spectacles or light bulbs, electricity in general perhaps. (Writer 1)

The part that was not traditional was the philosophical societal stuff. We thought that that has value and we thought that it was worth the effort of taking the risk that people will reject it because they didn't understand it or because they had no training in it, or they thought that it was just waffle and nothing to do with the real meat of the subject which is learning how to bang numbers into equations and get answers right. (Writer 3)

5.4.2 Intended Change: Differences in approach and not in content

In not wanting to alarm teachers with a drastically different physics curriculum, the writers kept the topic content almost the same as the existing prescription. However, they wanted to encourage a change in the approach to teaching physics in secondary schools. In particular, they wanted to see a more student-centred curriculum with lots of hands-on learning, questioning and experimenting, and not just students depending on teachers to provide the answers:

In a way we wanted to try and sell this stuff so we didn't throw teachers in a panic. We wanted them to see familiar stuff, we wanted them to recognise familiar stuff so they didn't feel like they've got to go and change everything. What we wanted to say is what you've got you will always be teaching, just the approach and how you do deliver it and your classroom should be different. (Writer 2)

... at a few workshops I said "look physics hasn't changed, it is just the way you are presenting it to students that has to be changed" and so I took a whole heap of things that we do and showed them how to use it in a different way. (Writer 2)

The writers were concerned to counteract the emphasis on the mathematical side of physics to the detriment of the conceptual side of physics:

We had seen situations where teachers taught up the front and they taught it quite mathematically; and if the students understood maths well, they did it. And that's often been the case with girls, that they understand it by doing the formulas, finding out how to correctly substitute into formulas. The exams examined in that way and you passed but you still have this general muddy feeling, and I can understand that, and that we see time and time again. So that was one of the things that we're trying to counteract. (Writer 1)

We put the importance on thinking, on understanding the concepts and principles of physics at the same time expecting them to be confident and manipulating equipment and setting up experiments, taking measurements, being observant; so all the traditional expectations. So what we would be interested in is that teachers take more interest in how their students were learning. (Writer 1)

In places in the document the writers felt that they had strongly indicated the approach to be taken by teachers to help students achieve understanding:

We've said a two to three week practical investigation that the student does that's monitored by the teacher. That's giving strong indication that we would like to see project work involved. (Writer 1)

It's different in that it spells things out a bit more, what's going on behind. So for example, the approaches to teaching and learning in physics, that is implied in some of this. (Writer 1)

While the content topics were kept almost the same as in the existing examination prescriptions that teachers used, the writers felt that the approach to teaching physics, such as using project work, more hands-on activities, less mathematical and more conceptual understanding emphasised, was a very desirable change and this underpinned much of what was written by them in the curriculum document.

5.4.3 Intended Change: A new look for practical work

The change in the approach included a change in practical work. The writers wanted the physics curriculum to go beyond just traditional experiments with recipe-type procedures and standard conclusions. They wanted practical work expanded to include students designing their own experiments, finding solutions to their queries experimentally by initiating investigations, and also undertaking long term project work. Thus the new curriculum had an emphasis on more hands-on practical work:

We definitely tried to make it perhaps a more practical course. It comes here in this box thing on page 6 of the final one, physics education, purpose of physics education is to develop enthusiastic learners, good communicators, good understanding of the basic concepts, skilled in practical investigation; to inject some dynamism into physics that is not stodgy heavily theoretical obscure; it's grounded in everyday events and things that they can see applications to it; that there was a fair amount in their own decision making and their own investigations, so they are not recipe experiments all the time, which physics is generally known for. (Writer 1)

The meaning of problem solving was distinguished from the traditional meaning in that the writers saw problem solving as being involved in solving real-world problems:

Now when we use problem solving it has two meanings, traditional meaning is solving physics problems, right, and doing ten problems, whereas we've tended to use the word problem solving now to mean that you've got a scenario of a real thing and you have to come up with a solution to it; that there is not necessarily one best answer but there are a range of answers that you choose from and justify why you like to do it. So we got one example of the investigative objectives at Level 7 is participating in a problem solving exercise that uses golf ball elastic as a bungee rope for an egg. (Writer 1)

Also the traditional way of conducting school physics experiments was considered not helpful for teaching problem-solving where all the steps of the procedures were given to the students. The writers wanted students to figure out the procedures for themselves and thus partake more in the problem-solving of the situation:

Newton's Laws, everyone teaches Newton's Laws, we felt that the way people introduce things "now here is an experiment to prove Newton's second law. Here is the equipment you are going to use, these are the results you are going to get; this is how you set it up". We wanted to get away from it, we still wanted to use the same experiments, you might have your ticker timer and your trolley, you know, load it with masses to get your graph of force versus acceleration. But we wanted the approach to teaching to be different so to the students, you know, "here's the problem, we want to look at the relationship between the force and acceleration; how are we going to do it, how are we going to set up the equipment, what measurements are we going to take, how many are you going to take, what are you going to do with those measurements?", so that they were coming through solving the problems themselves rather than being given that's the practical to do if you like.
(Writer 2)

Writer 3 distinguished investigations from the traditional school physics experiments. He saw the introduction of investigations as a major change in the way physics is intended to be taught in the new curriculum:

The one big way it is different is that it is making the investigations a big part of it. And also I think if you understand what's meant by investigations and why they are called investigations rather than practicals or experiments, then you will see that that's a huge change. ... there are some investigations which I've seen and done occasionally which are on such a scale that you wouldn't attempt a second one in the course of the year because they are so shattering. On the other hand you can design mini investigations which you could have in a circus and I could imagine you doing several in a term. (Writer 3)

5.4.4 Intended Change: Changing student perceptions of physics

The writers concurred with the Ministry of Education that the main stakeholders in this curriculum design were the students. With this focus they set about writing a curriculum that made the learning of physics more exciting and meaningful. They wanted to change students' perceptions of physics and the way students approached the learning of physics.

Writer 1 commented that students should take initiative in learning physics and to be able to make “mistakes” as part of their learning:

We knew the physics sufficiently well that we weren't hesitant and we wanted to develop that in our students, for them to try things and to risk things and be wrong. I now see when students are wrong I don't see that as wrong as such I see it as incomplete understanding, which is the constructivist side of things. (Writer 1)

Writer 2 wanted students to think and act like scientists rather than be mere recipients of information:

... and to try and make them behave as scientists. ... Then they can have a big discussion and eventually you lead them to come up to the idea that "OK this model doesn't work does it and what do we do as a scientist?" ... so you are actually making them go through a process of imagining what it was like to be a scientist and suddenly discover the things that you expected didn't work, rather than just say to someone that there are two models of light and this one works here and this one works here and that's why we've got two. (Writer 2)

The writers wanted to change the perceptions of both students and teachers that physics was a bounded mathematical study with limited horizons. They wanted to widen the scope of school physics to involve more critical thinking, deeper understanding and greater enjoyment:

... just introducing all those kinds of little things into your lessons will gradually change students' concept of physics as a tight little box and a number crunching thing and boring little maths formulas and... And we were hoping I think with this that it would change teachers, and we know that it won't happen overnight and we thought ten, fifteen, years perhaps, we might have teachers coming out who don't say, "Oh but this is physics, it has got to have a definite answer. (Writer 2)

Well we wanted them to get more enjoyment out of the lessons; we wanted them to be able to think and above all we wanted them to try and have some understanding of concepts. (Writer 2)

5.4.5 Intended Change: Incorporating formative assessment

The new curriculum required new methods of assessment. The writers were told by the Ministry not to worry about the summative assessments that would need to accompany the senior school physics curriculum. Instead they wrote examples of a

variety of assessments (moving away from pen and paper tests alone) which were useful as formative assessments to check for understanding from the students:

... we're looking more at formative assessment, feeding back to the students how they are getting on, rather than the summative assessment which teachers are most used to. (Writer 1)

However, the summative assessments that were later developed such as the Unit Standards were not considered by the writers to be suitable for assessing learning in the new curriculum.

5.4.6 Intended Change: Teachers constructing the classroom curriculum

The curriculum document laid out the aims and approaches for physics education in secondary schools. It was more of a curriculum framework with the next step being for teachers to write out their teaching programmes based on the guidelines in the curriculum document. The non-prescriptive nature of the document was intentional as it was specified that flexibility was to be built into it. However, the writers reported that this might raise the unease of teachers who had not been trained to design their own work schemes from a curriculum document which only provides the guidelines and not a precise account of what to teach:

The Ministry always wanted that for the teacher to have flexibility. Our worry was do the teachers have that expertise at being able to generate from a curriculum framework, a syllabus that meets all that and then every school was inventing their own syllabuses and that hasn't been in our mentality. We've had this where there's been a Department of Education and they tell us what to teach. Of course in some countries overseas it's even more prescribed, you know you will all teach exactly this. So that has been the big philosophical change that these are part of, that these have some degree of flexibility in them, they give a general guideline at the same time. (Writer 1)

Writer 2 described the way that they intended teachers to work from the curriculum document in designing their physics programmes; clearly distinguishing the process from past ways of planning their teaching schemes that were based on the examination prescription:

Because the way people learn at schools, they think what do I teach, what do I have to teach? In order to work out what they have to teach, they have a look at the prescription and see what is examined. And there is the exam and so I'll

have to do all that because that's in the exam; whereas this was meant to be the other way around. There has never been a curriculum for sciences, so this is saying, "you start with this and you look at this and you see that these are the outcomes if you like, the objectives that you are hoping to achieve, and so you write a programme, this is guiding you to what you could learn, what you could teach, and then you want to say "well how do I know if they understand any of these concepts?", so you design some assessment to give you that information. So it's meant to be the other way around. I mean I know teachers won't do that but we were trying to guide them, hoping that some will eventually do that. (Writer 2)

Writer 2 was aware however that for implementation of the new physics curriculum, the examination prescription mentality might result in some teachers looking to Unit Standards or other examination documents to plan and design their teaching programmes. However, she hoped that new teachers would be more inclined to start with the curriculum:

... That's what more people would do at the moment, would take the prescription or the exam or unit standard and then do their learning programme. ...from experience we know it. That's why we hope that this will change that. But we're realistic to know that a lot of it wouldn't. But I do feel some, yes it will, more and more new teachers will start with that (the curriculum). (Writer 2)

Thus a change set up by this curriculum was due to its non-prescriptive nature allowing for flexibility in its translation into practice. This meant a change in the teachers' mentality from wanting to be told exactly what to teach, as given in syllabus requirements and examination prescriptions, to working from aims and suggestions in a curriculum document.

5.4.7 Summary

It is possible to identify a number of the changes that the writers sought to bring about in writing the new curriculum. They wanted a student-centred curriculum, involving investigative practical work. They wanted students to see physics as an exciting creative human activity that impacts upon and is influenced by society. They sought to empower teachers to develop their own learning programmes, and use formative forms of assessment. The final curriculum document reflects these desired directions in the achievement objectives, the examples of investigative contexts, and the assessment examples. The curriculum developed was seen by the writers as being

very much a “curriculum framework” for senior physics, and so, one that gives the teacher the responsibility for developing their own teaching programmes for their classrooms.

Although the physics curriculum document was designed to promote substantial change in physics education, the writers did not have a naive belief that, with the publication of the document, the changes intended would progress smoothly. As many curriculum development projects reveal, what has been planned by change agents is often not what is enacted within the classroom (Fullan, 1993; Goodson, 1994; Hargreaves, 1993). In preparing the curriculum document, the writers’ experience of interactions with the community of practice of physics teachers revealed that there were very significant constraints on change that stemmed from their adherence to existing custom and practice. Some of the issues connected with these constraints will be considered in Chapter 6.

5.5 Conclusion

Chapter 5 started by describing the processes by which the actual writing of the curriculum occurred. Next, it described the factors that were influential on the development of the curriculum. These included external constraints such as the Ministry of Education’s contract and writing brief and also those internal to the writers as a group such as their own philosophies and the ideas of science educationalists that they held in esteem. These and the other influences described in this chapter were present throughout the development and writing of the curriculum document. Then the chapter went on to describe the aims of the writers in the development of *Physics in the New Zealand Curriculum*, in particular, the intended changes proposed by the new physics curriculum.

It is well to conclude that *Physics in the New Zealand Curriculum* epitomised the intentions and designs of a new physics curriculum for secondary schools. It was an eclectic array of intentions because the influences were seen to come from many directions such as the Ministry, the parent document *Science in the New Zealand Curriculum*, the Institute of Physics, submissions on the draft document but, especially, it was infused with the ideas, philosophies, passions and visions of the three writers. From a sociocultural perspective, *Physics in the New Zealand*

Curriculum was a cultural artifact that reified the vast plane of lived experiences of many stakeholders and embodied the intentions and aspirations of these stakeholders within its pages. However, the document is, in Wenger's terms, merely the "tip of the iceberg" as it is a reification that "can hide broader meanings in blind sequences of operations" and "can become a substitute for a deep understanding of and commitment to what it stands for" (p. 61). In itself the curriculum document cannot convey the deeper meanings of the intended curriculum and this is clarified in this chapter. It becomes a point of focus for the negotiation of meaning of a new physics curriculum when people use the document. However as one writer has commented, "the document needs further explanation to it", and that would allow a greater understanding and alignment with the intentions of the document during the negotiation of meaning organised around this reification.

The influences described in this chapter were the source of issues and debates that the writers had to resolve in producing the final document. The next chapter will describe the writers' consideration of a number of these issues and debates delving further into the plane of lived experiences that backgrounded the document.

Chapter 6 ➤ Issues and Debates: Writers' Views

6.1 *Introduction*

In Chapter 5, the writers' description of the process of writing the curriculum document alluded to many issues and debates that they had to grapple with in that process. In the following sections, the writers' explanations of these issues and the ensuing debates are described. The issues and debates are grouped under the following categories: the politics of the curriculum; the writing of the curriculum; and the implementation of the curriculum. These issues have been mentioned in the previous chapter but here they are re-categorised and dealt with at a deeper and more fundamental level.

6.2 *Political Issues*

The political aspects of a curriculum are often assumed or taken for granted by many researchers, and when addressed, they are usually taken to be concerned with the conflicting interests of various stakeholders and their power and control to bring about the changes that they desire (e.g., McGee, 1997). However, Wenger (1998) advances another meaning of what "political" means, that is, tied in to his dual modes of existence: participation and reification. In this way of thinking, the political movement of participation is to obtain curriculum changes through influencing powerful others; the political movement of reification is to obtain curriculum changes through documenting and gazetting the desired curriculum. As Wenger points out, the political aspects of participation and reification are not separate but complementary to each other:

No form of control over the future can be complete and secured. In order to sustain the social coherence of participation and reification within which it can be exercised, control must constantly be reproduced, reasserted, renegotiated in practice. (Wenger, 1998, p. 93)

In the subsections describing various issues that follow, Wenger's broader discursive meaning of the politics of curriculum is followed. The political is not confined only to the power of stakeholders to influence and decide, but includes the very processes of

the negotiation of meaning and alignment that render the final forms of the cultural objects contained in the curriculum.

6.2.1 Political issue: Curriculum document is a political document

Physics in the New Zealand Curriculum was developed as a commitment to curriculum reform in the 1990s when the National Party became government and Lockwood Smith was Minister of Education. It replaced the reforms started under the Labour government where a new science curriculum was drafted by Beverley Bell (Department of Education, 1989). Writer 3 outlines the positioning of the physics curriculum document in the confusion of the various curriculum changes that were occurring or had occurred in New Zealand:

Lockwood Smith's fetishes! It was largely Lockwood's dreams of it. Political context is an extremely rich and varied tapestry, isn't it? Prior to that, you had all the LISP research, you had the failed Form 1-5 curriculum from Beverley; never ever got gazetted, did they? Strange, you had the science curriculum itself; this (the physics curriculum document) was seen as an oversight and got tagged on to the end of that. You had the 'back to basics' movement calling for accountability in education and clear learning goals, which led to this which was one of the most unclear learning goals except they are trying to screw it down now by tying it down with these performance criteria in the Unit Standards thing. The whole thing's a mess. (Writer 3)

In fact, there were always political implications in all the work that the writers did. For example, the interests of various stakeholders, such as female students and Maori students, needed to be upheld in the document:

The girl friendly aspect of it, we're reminded of all the time, and that influences a lot of what got put in there. With the Maori or the ethnic issues, they caused a hell of a lot of strife. Oh! Only internally, in our writing group, in trying to come into grips with what is Maori science. We decided that this subject, physics, probably wasn't Maori science.... We didn't want to make any statement about the validity or otherwise about Maori science or any value judgements about its validity, but the history and traditions of physics aren't specifically Maori. (Writer 3)

6.2.2 Political issue: Relationship with the Ministry

The interactions that the writers had with the Ministry highlighted the fact that the writers were not considered as authors of the curriculum document. According to the writers, the Ministry (an unspecified team consisting of policy as well as operations

people) could do anything with what was written and also with the advice given by the Review Committee as they had the responsibility of developing a curriculum that was acceptable to the Minister:

So that was put in because after all we are only contractors; the nature of the contract is that we are there to do a job; we are not authors as such. ... and they can do anything with the advice that they were given by the advisory group too for the Ministry to develop a curriculum that makes the Minister happy. (Writer 1)

The Ministry defined what needed to be included and this was conveyed through the Curriculum Facilitator who was in charge of the physics writers' contract and a number of other contracts. The communication was through phone calls, faxes, mail and through face to face meetings when he came up to visit the writers. This communication bottleneck was frustrating to the writers:

We felt that the key communication would have been better that way; that we could have seen them face to face and said what they were because we were always trying to second guess everything and now what would they think about this and what did they think about that. (Writer 1)

Indeed the writers found that the time slippage that occurred was due in part to the lack of time available to the Curriculum Facilitator to service the contract:

So some of the slippage that happened was due to the fact that this one person was in charge of so many contracts and there were only four or so of those people in the Ministry in charge of 50 contracts or more. They were in three, four different parts of New Zealand in the one day. Yes, ludicrous! (Writer 1)

The lack of direct contact with the Review Committee was a situation in which the underlying concerns associated with their comments could be easily misinterpreted. For example:

It was our advisory group that was quite restrictive in a way because we would write a milestone and give it to them, they would send it back with comments, and then we would then take those comments and then carry on from there. That was quite restricting in a way because the information we got from them was from an intermediary, via minutes from that meeting and it wasn't until very late on in the project that (Writer 1) managed to get to one of those meetings, so we could get first hand what was happening because one of the problems we had at one stage, the brief that came back from the group was that the word technology was mentioned too much in the document. So we spent a long time talking about that and changing it when in actual fact we

didn't need to go that far. We'd misinterpreted information given to us. (Writer 2)

This situation meant that the writers felt that they were being forced to write the curriculum in a certain way. The expected way however was not clearly conveyed as there was a sense among the writers of dealing with unknown people at the Ministry. Writer 3 felt that the physics curriculum was judged on its correspondence to the science curriculum:

It is very hard to second guess what the Ministry's motivation was and it was very hard to ever find out who or what the Ministry was. We kept getting told that the Ministry feels that this is what should happen but no one really knew who felt what should happen. But I suspect one of the considerations, one of the impressions that we got quite strongly in our dealings with the Ministry was, this was initially in the early stages of it, that our document was being judged on how closely it corresponded to the science one. (Writer 3)

Writer 1 thought that some of the vagueness of feedback was related to the Ministry itself being unclear because the document emerged as an after-thought following the science curriculum:

We had difficulty visualising what the document was going to look like at the beginning, but this became clearer and clearer as time went on. Perhaps this was because the Ministry was not clear itself what the document was meant to be as it was almost like an after-thought by the Minister, and the Ministry had not geared themselves up for it. (Writer 1)

There were a number of occasions in which the writers were constrained and not allowed to write as they thought fit. One such example was when the writers wanted to write a statement to clarify the weightings of the achievement objectives and were not allowed to do so. The writers expressed frustration with the restrictions imposed by the Ministry. However, they felt that they still managed to achieve some of their ends in spite of ultimate Ministry power and control:

We wanted to be really emotive sometimes, like we wanted to put 'physics is a fascinating discovery' and all these kind of words and we have to scrap all those; they wouldn't let us have them. But we managed to get in 'knowledge, skills and attitudes in physics thoroughly, equitably, and with affection and enjoyment' and we managed to push for that. (Writer 2).

6.2.3 Political issue: Constraints of the Ministry's brief

The constraints faced in terms of the pre-defined structure of the document have already been discussed in section 5.3. Writer 3 found the constraints in the Ministry's writing brief very confining and at times impractical:

The basic structure of it was pre-defined, yes.... It was as comfortable as a millstone, it was useless.... Not that it was too restrictive but that it was conceptually flawed. The whole thought, the whole idea that you could encapsulate a curriculum within about half a dozen sentences which perfectly encapsulated everything was just nonsense. (Writer 3)

The concept of levels was an important one for the document, yet the writers were not clear how to deal with it as the Ministry did not define it for them according to Writer 3. He could identify difficulties for classroom physics teachers in utilising a 'one child one level' approach:

This whole concept of 'level' was just not defined. They insisted that we write it at three levels ... I personally wrote some long letters to the Ministry explaining how this concept of level led to difficulty and that you couldn't, it was very difficult to define what was meant by level and that there were different senses in which the word level could be understood, and asked them which one they were expecting us to use when we wrote the document. We never ever got any clear guidance back from them about what they meant by it. (Writer 3)

The writers felt some satisfaction in the decision that was taken for the final physics document to tie content to the levels because of complaints about their lack of clear inclusion in the draft curriculum document. However, there was a problem in tying content to the mandatory levels because the implication was that teachers do not repeat topics at different levels. They remarked that, previously, topics were revisited every year, going a bit deeper into them or just being revised. However, with the achievement levels in the new curriculum, the content had to be split up into the different levels and written very carefully given the stipulation that once a topic has been achieved at a certain level, they shouldn't need to achieve it at the next level; thus there can be no repeating of topics in the different levels. The writers did some swapping around of existing content topics for the different levels based on their experience as physics teachers.

This was foreseen as a problem of concern for teachers due to there being less than 15% of secondary schools offering physics as a subject at Level 6. Most schools introduce the specialist science subjects at Level 7 (i.e., Year 12). The writers were aware that the students who pick up physics in Year 12 (i.e., the majority of physics students) would have to cover Level 6 topics so as to be able to do the Level 7 ones. Keeping this in mind they divided up the topics between Levels 6 and 7 so as not to cause overloading at Year 12.

Now the problem with that is that it ties levels to content, whereas the original intent of the eight levels that the Ministry hit upon in the curriculum framework is that those levels are due to an individual student's development. (Writer 1)

So there is nothing on Newton's first and second law (in Level 7). Now what will happen is if the school doesn't teach fifth form (Year 11) physics, those students (Year 12) will have to do that and the stuff that is at Level 7 altogether in order to be able to do the Level 7 stuff. (Writer 1)

6.2.4 Political issue: Language of the curriculum

Associated with the constraints on writers in terms of the achievement levels, there was the language of the curriculum document. The choices that writers made and were constrained to make were political. The curriculum framework derived from a political agenda. The writers acted as brokers between communities of interest including teachers and thus were part of the political process themselves. The language choices that permeate the curriculum arrive out of the political nexus.

In Writer 3's view it was not possible for the document to unambiguously encapsulate the curriculum in such a summary form. He questioned the so-called neo-behaviourist underpinnings of the writing brief believing that given some other stipulations in the brief, the achievement objectives could not be measured:

There were constrictions on the verbs we use there, and there was also a general stupid thing that was imposed on us that each of those performance objectives was meant to be measurable. So there was a behaviourist constraint imposed in the brief from the Ministry. Although that was a tension, that was a hell of a tension, because how do you make it sufficiently general to cover the whole syllabus in six statements and yet sufficiently specific to be measurable? It's not neo-behaviourist, it's just crap. (Writer 3)

Writer 2 mentioned the difficulty in finding appropriate words to distinguish the difference between levels in the curriculum document:

Some things were quite difficult. You know if you were going to do some practical work, investigations, how can you split up a level? I mean we know there is a maturity involved in investigative work. You can see the difference between a student operating at a Level 6 and someone at Level 8, but how to actually mention that in a document? How do you actually talk about that? We had problems with 'carrying out investigation with supervision, with guidance', or you know, trying to pick words. That was hard. I think trying to pick words to explain what we meant was a restriction. (Writer 2)

The writers attempted to use coded words to convey a hierarchy of difficulty so as to distinguish between the different levels of the achievement objectives. However they found that these coded words were not precise in their meanings and could lead to confusion:

The other problem that we had with this draft was the fact of coded words, of using coded words, that is, you had words such as carry out, explore, describe, develop, analyse, explain. All of those words have coded meanings and have a hierarchy of difficulty or sophistication. But it's all relative... (Writer 1)

6.2.5 Political issue: Assessment

The writers identified the issue of the political influence of NZQA (New Zealand Qualifications Authority) as a separate Government organisation. They feared that the Unit Standards approach to assessment being trialled at schools might result in the curriculum aims being fragmented and teachers wrongly adapting the curriculum:

We have this broad curriculum now which NZQA now has taken over with their Unit Standards, spelling them out and in some cases, I feel, wrongly adapting what we were trying to do in that curriculum. We thought that this would happen. We were afraid that it would happen. It hasn't been as bad as what we thought it could be but I still don't think that they are able to, the Unit Standards are able to assess the 'nature of physics' aspect to the curriculum that we put in it. (Writer 1)

At the time that they were writing the curriculum, the NZQA person on the advisory group reassured them that they need not worry about assessment when they were writing the curriculum as NZQA will change and adapt their assessment to the new curriculum. When the Unit Standards were being developed, each of the writers was brought in separately from time to time to attend their expert panel meetings.

Writer 3, discussing the writing brief that they had been given, described how one of the ideas, similar to that of the Unit Standards approach introduced later, impacted upon the extent of their curriculum considerations and indeed the very content of the curriculum:

You see this whole business of leaving the assessment considerations to one side turned out to be a gigantic conceptual flaw in the whole thing because the concept of Unit Standards was not yet invented and nobody knew the sort of dogma that was going to surround them when they eventually came into existence. So we wrote our curriculum and then what we found happened was that one of the tenets of Unit Standards was that something that was examined at one level, was assessed at one level, could not then be assessed at another level. And that really conflicted with the idea of a spiral curriculum where you would introduce a topic maybe one year and you would develop it a little bit further the next year. At one stage we got told maybe you mentioned Newton's Second Law in Form 5 (Year 11), well you can't do it again at a different level because it can't simultaneously be at two different levels. Well that's actually crap; it can. (Writer 3)

Philosophically the authors had reservations with Unit Standards. Moreover, by the time that they had completed their writing, the Unit Standards had been formulated and the writers saw it as subverting the implementation of the curriculum:

So one of the things we thought of was this document was not going to be used at all because people are immediately going to wait until the prescription comes out which is based on this and just teach that because that's what is in the exam. So it was quite hard to think through that. (Writer 2)

I would imagine that a lot of the philosophical rationale for why things are in here is going to be lost when you get this big monolithic assessment dogma (Unit Standards) imposed onto all of it. (Writer 3)

6.2.6 Political issue: Subverting the original aim

The writers had philosophical issues with two aspects of the new curriculum: one was the content-free achievement objectives statements when writing the draft document, and the other was later on when Unit Standards was developed for assessment of the new curriculum. For the first aspect, they supported the submissions that achievement levels should be tied to content.

They saw this as also bearing on a difficulty of the Unit Standards having an invariant sequence. For example, Writer 1 described the way that the Unit Standards specification was unreferenced to content in the case of graphing data:

Then the practical investigations, they've actually teased that out and they said, "Right, one Unit Standard is on being able to identify trends by graphical means and that one stage it has to be a linear graph and another one it has to be a non-linear graph." Now that I don't like particularly, because I think that even at fifth form, you will have situations with non-linear graphs, that you can interpret still and extrapolate, things like this. So to be able to go back to specifics and say, "Look, we'll go from linear to non-linear to logarithmic" is too artificial; I don't see as being good. (Writer 1)

In the final document, the same objectives were present but they were tied down to the content given in a list below the objectives in the document, and that determined the level of difficulty of the objective. Thus Writer 1 felt that there was subversion of the ideology of the original framework which did not intend the objectives to be anchored to any content topics:

We have said now something that perhaps we were loathe to say at the start, that is, "in Form 7, you do circular motion in the form of circular dynamics, rotational dynamics, whereas you don't do that at Form 6 or at Form 5." The problem with this is that levels are tied down to content. This was not the original intent of the eight levels by the Ministry in the Curriculum Framework where those levels correlated to individual student's development. So we have and we've been allowed to, believe it or not, in a way, to subvert that free and diagnostic level idea. ... We don't think it's a problem and it hasn't affected the ethical nature of what we do. (Writer 1)

The rules about non-repetition of topics at the different levels obscured the fact that, often in the classroom, teachers have to teach the same topics but perhaps at a deeper level:

That (re-teaching of some topics at a deeper level) was exactly how we always knew how it had to happen, and it seemed ridiculous to us that we were being prevented from being clear about it; we were then forced to obscure that fact. (Writer 3)

6.2.7 Political issue: Writers' attitudes

The writers brought their own values, beliefs and attitudes into the writing process. While they did not always feel that the constraints imposed by the writing brief reflected their attitudes in all respects, they got around that feeling by the notion "we

were three people that were committed first to physics and then we work within those constraints for the benefit of the physics teaching world” (Writer 1). Writer 1 expressed this view further by commenting:

There is a degree of behaviourism, behaviouristic philosophy, involved in the levels and the breaking them up into achievement aims, and these are measurable things. ... Now, that was imposed upon us by the system and within that we have tried to be true to physics: being essentially not in agreement with that philosophy, what’s the best that we can do in that system. (Writer 1)

Writer 3 felt that the new curriculum would require more funds to run but said that they made a decision to write the curriculum without worrying about such issues:

I think we made the decision that to hell with the funding and we would write a curriculum which is a curriculum we would like to see in this country, and we would like to see it funded. I think to implement this curriculum in the spirit in which it is intended would be an expensive exercise. (Writer 3)

Thus the curriculum embraced Writer 3’s fundamental goal for physics students:

One of my, sort of, fundamental goals in all this is that you produce kids that are actually capable of working in a context in which they haven't worked before, but are able to relate it to other context with which they are more familiar and are therefore able to find the way of working in a novel situation. (Writer 3)

6.2.8 Summary of political issues

There were a number of political issues that arose out of the writers being in the process of developing an artifact about which alignments of the future would be realised. Thus the writers had to produce a document that would satisfy the vision of a Minister of Education of a right-of-centre National Government, a Ministry working under a modernisation brief that constrained their writing with neo-behaviourist elements, and also to convey to the community of physics teachers the vision of physics teaching that they had as progressive physics educators. Clearly there were a number of political decisions made by all parties that influenced the writing process. The next section outlines the issues associated with the writing process.

6.3 Writing Issues

6.3.1 Writing issue: Aims and objectives

At the core of the writers' work was the development of the themes or strands for the achievement objectives at Levels 6, 7 and 8 and the specification through language of the objectives at each level. There were considerations such as content, investigations, physics in society and other educational issues in physics.

The writers looked at the science curriculum document's physical world strand but they found that there was an artificiality in the energy strand that they did not agree with:

I felt in the science curriculum, I'm mentioning energy all the way through and you had to think up something useful for energy, right from up J1 (Year 1) to Form 7 (Year 13). That got a bit artificial, you know, there might be other stages where it would have been better to look at forces rather than energy. (Writer 1)

As well as removing the energy strand in their statements about the aims of the physics curriculum, they amplified the other three achievement aims of the science document. They included the understanding of concepts, principles and models *per se*. They included the understanding of the social human origin of these aspects of physics and their applications. They also included, as part of the aims, the investigation of the utilisation of physics concepts in understanding applications and phenomena.

The writers saw the first strand of concepts, principles and models as forming the backbone of physics. The utilisation of the idea of models was seen as an innovation compared to the previous prescriptions. The writers reported that they saw theories in physics as models of what was happening; mathematical models or conceptual models.

They wanted concepts, principles and models to be lasting impressions with the students and, further to that, to be able to apply those concepts to explain actual physical phenomena, systems and devices. The idea was that as they applied these concepts, they would be deepening their understanding of those concepts and

principles. So concepts and principles were seen as a backbone in deriving all the three strands of the physics curriculum.

The third strand was to do with investigations. It required the carrying out of practical investigations to determine relationships as well as to describe applications of physical concepts. Investigations included investigating applications of physics concepts and applying the physics investigative procedures to an existing piece of technology.

The second strand was a less well-defined aspect of physics where the nature of physics and its influences on society were to be studied. The writers were interested in students being ...

... able to step back from the physics that they are learning and critically examine physics. It can be practical, it is looking at the philosophical nature of physics, the historical chronology on how physics was developed. So this aspect of physics that was introduced is the fact that physics is a human activity and has people that do physics, and so society and culture apply to it too, for example, 'Describe influences of everyday physics-based applications on people's lives.' Both historical and contemporary aspects of physics were included. (Writer 1)

Ethical and moral issues could be included in this objective but the writers did not regard it as an aspect of the curriculum to be included in the examination prescription as they felt that it should not be examined:

I wouldn't like to see that being examined, the ethical and moral issues, but certainly I would expect that to be mentioned that people are people and physics is second so to speak. (Writer 1)

The writers had an interesting framework that was the guiding force in the progression in the levels for the three strands. As stated by them, the levels reflected the following attitudes:

Level 6 - "gee whizz isn't that interesting" (simple).

Level 7 - "Oh isn't this useful" (philosophical).

Level 8 - "Oh how powerful and all encompassing" (critical).

These ideas formed the hidden basis for many of the examples and aspects chosen for the different levels.

The three strands for aims that the writers settled on were formed fairly early on in the writing process and thereafter the writers engaged in the process of refining them. The three strands were seen as linked and it was specified in the document that they were to be integrated when taught. The writers believed that students should appreciate the interwoven nature of these aims:

Yes, it's in the actual physics achievement aims which are the general ones not the specific achievement objectives: one, the order of the aims does not indicate their relative importance; students should also appreciate the interwoven nature of these aims in that all three aims should be seen as essential aspects, and we also bring in this language, developing their physics vocab, and that investigative skills and attitudes are already prescribed in the Science in the New Zealand Curriculum. So yes it's that interwoven aspect, that was written almost in the first few drafts. (Writer 1)

The order of the aims was rearranged in the final document. In the published draft document, they had on purpose put 'concepts and principles' as the last one on the list of aims and objectives to see what feedback that received. However the writers were ambivalent about the order of the aims and put a note into the final document that the order of aims does not indicate the order of importance. In the feedback after publishing the draft physics curriculum document, there were some totally different suggestions on how to write the aims by some tertiary physicists, and others, such as looking at the big picture involving six greatest physics developments, or tie curriculum to a good textbook, or to tie with other courses internationally. These were not acceptable to the writers.

The writers had issues related to the specification in terms of separate aims. Writer 1 suggested that "We see these all as an artificial teasing out of essential aspects of physics." The problem of this separating out of aims became obvious in the formulation of examples showing the interrelatedness of objectives:

Yes it became a problem for us when we gave examples ... You know as soon as we gave an example in a particular achievement objective, it's quite obvious for many of them that they could fit into some of the other achievement objectives, that they bridge several of those achievement objectives, and that's why when you are teaching it is very hard to separate out those objectives. (Writer 1)

The specification of aims raised issues for the writers that related to their coming from elite equipment-rich schools as some aspects of the aims may require the use of sophisticated equipment not available in poorer schools:

....but we were very careful to consider the views of others rather than just three of us, because we were very conscious of the fact that the three of us came from, elitist schools if you like. (Writer 2)

In the end, the writers were satisfied that the aims that they set out were not too disparate from those that currently existed. This was vividly illustrated in an anecdote provided by Writer 3:

That was one of the things that (Writer 1) used for a little trick occasionally at various meetings. He said, "Look at these aims", put them up on a screen at a meeting and say, "Where do you think these aims come from?" and people would say, "Yea that looks like the new curriculum" and he'd say, "No, it's the one you are using now." (Writer 3)

Thus the aims in the new curriculum document were similar to the aims in the old examination prescriptions. The main difference is that the aims in the new curriculum are made concrete in the form of achievement objectives for the different levels; that then would make them a focus for teachers to teach from and measure achievement. Whereas in the examination prescriptions, the aims were not the focus for teachers whose main focus is the topics of the syllabus to be taught and the weightage of the various topics for assessment.

6.3.2 Writing issue: Curriculum without reference to assessment

Writing the curriculum without reference to the assessment framework assumed to be dominant (that of Unit Standards) was a curriculum development issue for the writers. They were acutely aware that there was no guarantee the values and objectives which underlay their work would be congruent with those of the NZQA Unit Standards. Writer 3 suggested that he would have liked to have included the question of assessment, even possibly starting with that as the curriculum was being fashioned. The danger of the assessment obviating the thrusts of the curriculum document is highlighted in his comment:

I would start at the other end of it, I would probably start with the assessments, if they wanted to do it in a sort of linear fashion, they'd better have started at

the other end from what they started and to work out the exact sort of things they want kids to be able to do and the way they are going to assess them and then trace that back and figure out how they sort of summarise it with these little pithy statements after they've got it all worked out. But you can't work that way entirely either because then you can't see the wood for the trees and what you are doing. You don't get an overview of where you are going. But to come from one end to the other is almost equally bad regardless of which end you come from. You've actually got to keep the whole picture, the whole process in your mind the whole time. ... And I would imagine that a lot of the philosophical rationale for why things are in here is going to be lost when you get this big monolithic assessment dogma imposed onto all of it. (Writer 3)

The importance of assessment that supports the thrusts of a curriculum is emphasised. It is often talked about as “the tail wagging the dog” when an assessment structure does not support the curriculum and is seen as a huge obstacle to its implementation.

6.3.3 Writing issue: Lack of support document to aid interpretation

At the time of implementation of the new physics curriculum, there hadn't been time or resources that allowed the writers to write up explanations of the curriculum in supporting articles. The writers had done some limited public speaking justifying what was in the curriculum document and verbally giving their vision. They saw this involvement as limited although they had done a presentation to the teachers attending an Institute of Physics conference.

I don't think that it's quite adequately had enough explanation to it. And it is partly because we haven't had to implement it yet that that problem has not surfaced yet. So in the next couple of years that will surface where people will start to do perhaps funny things with it. However, compared with the draft, it is much tighter; that was also done on purpose. (Writer 1)

They were told that there would be another document such as a Teachers' Guide developed to support the curriculum document. However the Ministry of Education did not fund the guide and that supporting document never came into being. Writer 2's comments below highlight that the writers felt the need for such a guide in order to allow teachers to access the intended meanings contained in the words of *Physics in the New Zealand Curriculum*. Writer 2 thought that a guide would also have allowed teachers to understand the way in which knowledge is not so compartmentalised by year level as the curriculum document would suggest:

Originally there was going to be a teachers' guide. Well we were told there was going to be one and we probably thought that we were going to be writing it; but then money constraints. There are no plans, the Ministry closed on it.... Um, because we wanted to write explanations, we wanted to be able to really pin point, you know, have a glossary of terms, for things like 'describe', 'explain', you know, those words that you bandy around, we spent ages, you know, we would spend hours philosophising on the use of each one of these little words, and to try and convey what we meant. In just one example, one day, I think two of us have done some work and we were discussing this and our impressions of the work and we had totally different interpretations, and then the third person came in and had a totally different interpretation of the work, of what we were trying to do. So when you got that, we realised how hard it would be for our philosophy to come out in some words. We wanted to have a glossary at the back saying 'explain' means, and give an example to the level, but we weren't allowed to do that. ... so really what we have to do, really we need a little explanation with this to say that we appreciate that in order to be at this level you got to have that bit of knowledge. So really when you are teaching 7th form, you got to teach that, and at 6th form you got to teach that as well. (Writer 2)

The writers felt at a loss as the new curriculum was not trialled and the only explanation of the new curriculum was contained in the curriculum document itself. They realised the difficulties of teachers grappling with trying to understand what was required in the new curriculum as the document was only a framework that needed far more explanation to make it understood. The explanations lay in the hands and minds of the writers but they were not supported to be able to expose this understanding to the teachers who had to try and make sense of the document by other means (see Chapters 7 and 8).

6.3.4 Writing issue: Curriculum versus prescription

The writers wanted to shake off the idea of a prescription that has been entrenched in the past and be very conscious that they were writing a curriculum. Thus there would be aspects of a curriculum that would be harder to demonstrate or assess than the elements of a prescription:

....very conscious that this is a curriculum that we are writing and not a prescription, and that this is the first time in the history of New Zealand education that there is a physics curriculum and wanting to explore what that meant and to, in a way, shake off our ideas of a prescription into a curriculum. So there are things here that will be difficult to examine than in a prescription. (Writer 1)

In fact, Writer 1 described what they were writing in terms of it being more of a 'physics curriculum framework' rather than a physics curriculum:

One of the main things about this curriculum is that it is a curriculum framework. I think in the international sense, in the international understanding of curriculum, this is only a curriculum framework; it is not a detailed curriculum. It's a broad brush painting of what physics should be like in schools. (Writer 1)

To have teachers develop their teaching programmes from such a flexible framework was seen to be a major shift by Writer 1:

The Ministry always wanted that for the teacher to have flexibility. Our worry was "do the teachers have that expertise at being able to generate, from a curriculum framework, a syllabus that meets all that, and then every school was inventing their own syllabuses; and that hasn't been in our mentality. We've had this where there's been a Department of Education and they tell us what to teach. ... So that has been the big philosophical change that these are part of, that these have some degree of flexibility in them, they give a general guideline at the same time. (Writer 1)

Writer 2 suggested that the achievement objectives being not totally specific but giving teachers some freedom was a decision made by the writers to differentiate the curriculum from a prescription.

That (not being very specific) was deliberate because that was not the role of a curriculum; that's a prescription for an exam. (Writer 2)

Writer 2 explained the danger of the power of the prescription over the curriculum stating that the focus of the teachers would be on the content of the prescription rather than the ideological directions of the physics curriculum document:

We were thinking of the way that teachers are going to use it. Because the first thing they're going to do, as soon as there is a prescription, is use the prescription. We're hoping they wouldn't but we ... know that's something that teachers would do. So they'd wait for the prescription and if the prescription didn't mention things that were in here then no one would do it. (Writer 2)

Thus the work of the writers was concerned with the framework for physics education, and not being overly prescriptive about its content. However, there was a quandary about the level of open-endedness that the curriculum should allow. Writer 3 expressed this issue eloquently:

With the curriculum that is too open-ended, you will not fulfill your obligation to give sufficient guidance to those people who need it and with a curriculum which is too rigid you will rob creative teachers of the opportunity to do the best for their students. So I compromise. ...If anyone's writing a document for me it better be open-ended, if I'm writing one for someone else (laughter), well no there is no solution. The best would be to come up with a compromise of some sorts which people at the either end of the extremes are going to be unhappy with. (Writer 3)

Examination prescriptions were written for the new physics curriculum and there was a real worry for the writers that the teachers would not be using the curriculum document that they had worked so diligently on. The writers felt that teachers would rather deal with the prescriptions for their teaching as that was what they were familiar with and they were not trained to develop teaching programmes from curriculum frameworks. Flexibility, though the salient feature of the new curriculum, was not necessarily ideal for some teachers who may prefer the concreteness of prescriptions.

6.3.5 Writing issue: Time constraints

One thing that affected the writers was the amount of time that they had to meet deadlines. Sometimes they had to ask for more time because, otherwise, they would rush through things without feeling confident that they have thought them through sufficiently or checked them out enough. Writer 1 admits that the final curriculum document could contain errors:

No, sometimes we asked for a week past the deadline and generally got it too; but even then, from what I've seen of several contracts, this is the nature of these things, that with the best will in the world there are some things that creep in or inconsistencies that creep in due to people working late into the night, the night before something is due, which over time will be repaired. You see I don't see this curriculum as being something that is immune from correction or mistakes. (Writer 1)

6.3.6 Summary of writing issues

The issues that arose during the writing of the curriculum included those of compliance with the Ministry's writing brief for Achievement Levels; the way in which assessment was portrayed in the curriculum; the development of a framework that forced teachers to make professional decisions about the exact form of the

classroom curriculum. It was in the writing process that the writers became aware that a 'thin' curriculum document would allow misinterpretation of what they had written; a false clarity (cf. Fullan, 1991). Thus, they were engaged as writers in considering deeply how the teachers would transform their practice during implementation with respect to all the aspects of *Physics in the New Zealand Curriculum*. The next section looks at the implementation issues that the writers considered when writing the physics curriculum.

6.4 Implementation Issues

6.4.1 Implementation issue: Pedagogy

The writers did not want the document to be coercive in any way, that is, forcing teachers to teach in a particular way. Thus, they felt that the document that they wrote allowed for a variety of pedagogies such as a traditional didactic style, using a guided discovery approach, emphasising contexts, and/or using project work. Writer 1 pointed out that the curriculum document did indicate that teachers might include project work as part of the curriculum:

That's giving strong indication that we would like to see project work involved. We debated the fact that every other subject is bringing project work and internal assessment in all the other areas ... And we debated the fact that able students often take music, sport and then they have to do practical work at the same time in several subjects; it is really quite a load. ... Yes, so we are aware of some practical problems but we still see that as important. (Writer 1)

The writers wrote the document aware of the different teaching approaches that they had witnessed and wanted to give the teachers the flexibility to use their preferred approach. However they were clear about what they wanted to achieve by the new curriculum:

We have in the back of our mind the type of teachers, again the idea that we wanted to develop something that could be used in any way for teachers, contextual or just traditional. ... Yea, guided discovery and that's why really you have to reduce the content. We felt that if they could come out with some basic understanding of some concepts, that was far better than regurgitating a whole lot of facts and meaningless stuff and never really appreciating the physics. (Writer 2)

Indeed the writers were aware that the reality of teaching is that any one teacher does not adopt a single style. The approach taken was often dictated by considerations other than just what is the best pedagogy. Writer 2 noted that because of time constraints she herself often taught using a traditional approach including talking in front of a class, notes, and worksheets. However in her opinion, to teach just using a traditional approach was not enough:

I mean I teach a lot of traditional stuff purely because it's necessity of time. ... but I'm always trying to do it in this way (student-centred methods, hands-on) because I don't think you are going to get students involved in physics unless you do show them that it is not just a tight little box. (Writer 2)

Writer 3 suggested that the achievement objectives were such that they were not an impediment to any particular pedagogy:

Even if those achievement objectives are set in concrete I don't think that really places too much constraint on being able to develop the psychological or the pedagogical style. ... No we are not promoting a particular learning style. (Writer 3)

Writer 2 talked of how the document was meant to reassure teachers that, in terms of content, nothing had changed but he claimed that the writers wanted teachers to reassess their teaching approach with respect to the thrusts of the new curriculum. However, the danger was that teachers would focus on the unchanged content and be reassured wrongly that they were already doing what was required in the new curriculum:

Well because teachers are slow to change and physics teachers particularly I would say are in that mould. Yea we realised that you can't change overnight everything. So what we wanted to change was their approach when teaching the subject and we felt that the best way to do that was to make sure that all of this (content) was familiar and some people have picked it up and said, "This is what we're doing", because they haven't read this (the rest of the document), they haven't looked at that, just looked at this (list of contents) and said, "Oh we're doing that". (Writer 2)

Thus, the writers' considerations led to a curriculum that they felt was not pedagogically constraining. However, via the sections on 'Introduction', 'Approaches to teaching and learning in physics', the learning examples and sample learning contexts in *Physics in the New Zealand Curriculum*, they indicated the factors which imply certain pedagogies that would enhance physics learning. Thus there seem to be

conflicting underlying messages within *Physics in the New Zealand Curriculum* with regard to pedagogy.

6.4.2 Implementation issue: Students

Another issue that the writers described as underpinning their considerations when developing the curriculum was the need to be able to teach students with different learning styles. For example, their discussions considered maturity and gender:

There were a lot of philosophical discussions about maturity of students and how they can handle certain physics concepts and at what levels that certain physics concepts should be introduced. (Writer 2)

I mean girls particularly, unless they see an application of a point, they switch off. ... Boys accept things a lot more easily. You can just teach them a whole heap of things and they'll accept it, but I don't think they get as much fun out of it.

(Writer 2)

This issue was brought to the fore in their own considerations of the curriculum when they realised that amongst the three writers there were two distinct learning styles and that students also would be learning in many different dimensions. This enhanced the degree of critique they put on their writing about whether they were attending to different learning styles among students:

So that was interesting and useful for us in debating these things is that there were two different styles of learning that we as a group of three had, and it was useful to consider from this point of view ... And we get kids learning in all those dimensions and more. (Writer 1)

The type of physics students that the writers wanted to see emerge from this curriculum is encapsulated in the bullet points given in the section on the purpose of physics education (see Appendix A5). They are to be independent, enthusiastic learners and good communicators; have good operational understanding of basic concepts; are skilled investigators and problem solvers; understand the nature of physics and interrelatedness of science, technology and society; work cooperatively with others and maintain scientific integrity in their pursuit for knowledge. These goals will demand the teacher to explore more student-based teaching approaches.

6.4.3 Implementation issue: Philosophical and societal aspects

There was a lot of debate over the second strand (Achievement Objective 2) which deals with philosophical and societal aspects of the physics curriculum. The writers wanted it to be about a tenth of the year's work and not a third as they felt it was probably being wrongly interpreted by teachers because there were three main strands of objectives. Also they felt that it should be taught as part of an experiment, part of various concepts and when dealing with the development of certain theories and models, that is, integrated among the other strands.

A key issue about strand 2 for the writers was that while they as writers enjoyed considering societal and philosophical issues associated with physics, the question was whether it was what the students should know and learn. They were concerned whether the students were ready for discussions on philosophy of physics and whether they would want it:

Our key worry is that (Objective 2 was included) because that's where the three of us are or is that something that students should know and learn. (Writer 1)

Another worry for the writers was that teachers might not understand the point of including Objective 2 which, unlike the other two achievement objectives, was considered quite novel and not related to teachers' existing custom and practice:

The part that was not traditional was the philosophical societal stuff. We thought that that has value and we thought that it was worth the effort of taking the risk that people will reject it because they didn't understand it or because they had no training in it, or they thought that it was just waffle and nothing to do with the real meat of the subject which is learning how to bang numbers into equations and get answers right. (Writer 3)

Nevertheless, Writer 3 had experience of students becoming passionate in discussions on the philosophy of physics and felt strand 2 to be fundamental and a core of physics learning:

That's not social studies, it's the core of what science is, the philosophical stuff, especially when you come to ask a question like "what is a law?" How do you know that the law is true? Are any laws true? Is a law only true plus or minus a certain amount and if it is only true to a certain uncertainty, is that true? You are really questioning the status of physics or science and you are

questioning whether you really understand the instrument that you are using, this thing called physics. I think it is fundamental. (Writer 3)

6.4.4 Implementation issue: Contexts

The use of contexts for teaching science was a characteristic of *Science in the New Zealand Curriculum*. The writers of *Physics in the New Zealand Curriculum* also seemed to emphasise a contextual approach to teaching with a section on ‘Sample learning contexts’. An issue that the writers deliberated on was that of the meaning of context and its place in the physics classroom:

Contexts perhaps to me means you choose the context of the motorcar and then you look at the parts of the motorcar, the battery, the motor, the rest and use that to do your physics. That to me is a contextual approach, the way I've just described. (Writer 2)

In the sense that we tried to give teachers the freedom to teach, just as I said before, if you had a rural Auckland community, you will pick on things, teaching contexts, that were applied to that community. I think at that level of your teaching strategy or designing your local school teaching programme, if you are in a Maori community, then you would choose contexts or whatever that were appropriate to the people you are teaching, and we felt very strongly that there should be enough flexibility in the curriculum to allow teachers to do that. But not just to cater for Maori, certainly to cater for Maori, but to cater for rural kids or whatever. (Writer 3)

Even though the writers were emphatic that they were not promoting contextual teaching, the section on Sample Learning Contexts in the curriculum document (derived from the science curriculum document) seemed to contradict that. The confusion that arose from the issue in this section is discussed in the following chapters on teachers’ interpretations of the new physics curriculum.

6.4.5 Implementation issue: Content

The writers felt that physics could not be taught without specifying content as in topics to be taught. Thus they diverged away from the energy strand in the science curriculum which did not really specify the content of the physical world section:

We realised that we needed content. You can't teach physics without content. And the energy strand that was in the science curriculum really had no place as a separate strand in our document. (Writer 2)

They were also aware that content was going to be of prime importance to the teachers as they considered the new curriculum:

... the first page people will open is that (page on contents), these (the other pages), they might go back afterwards and look at these ... but open at that (contents), and think “what have I got to do?”, this is what they would read first. (Writer 2)

To arrive at the content for the physics curriculum document, the writers began by studying the old prescriptions and considering what they wanted to retain:

We looked at all these old prescriptions and really decided what we felt should go in. We didn't want to change it too much because our aim was to change the approach and ... our objective was to have students coming out of physics with some understanding and appreciation of the subject. (Writer 2)

The writers delayed the final specification of the content until late in the development of the curriculum document. The reason that they did not write the curriculum by considering content initially was that they were not sure what content to include and they wanted feedback on the first draft to help in that area. In writing the curriculum, the writers felt the responsibility of determining the core curriculum content for the next ten years of physics education in New Zealand:

So what we wanted was more feedback as to what the people, what the teachers especially, thought as being important to teach. Because here we were faced with the enormity, basically three of us, of deciding what would be taught in the next ten years or so. (Writer 1)

The feedback that they did receive indicated a strong desire to have content specified. There was content given in the draft document but it was not prescribed but given merely as suggestions. This was found unacceptable by physicists:

What happened was that you end up with statements in some of the drafts and maybe in the first published draft, we had statements saying that concepts, principles and models suitable for developing at this level could include the following; which gave a list but gave you the freedom to depart from that list. But that was regarded as unacceptable because the universities hated it because the schools might not include all of those things and they might do some other way-out things and it just didn't tie it down as far enough as they were concerned. They didn't want those namby pamby new age rubbish. (Writer 3)

Writer 3 added that the feedback enabled the writers to prescribe content that covered specified physics concepts in the final document but he felt that it still left room for teachers to decide on the approaches to teaching those concepts:

So what we ended up with in the final version of it, we have actually said that content will be based on the following concepts and we've just mentioned concepts such as kinematics equations for translational motion in one dimension which gives the teacher reasonable professional freedom about how they are going to teach that topic but says "thou shall do it", you know you still got to cover it. So maybe if this is to be regarded as a curriculum which gives people professional room to manoeuvre in how they teach, it's OK. (Writer 3)

The writers mentioned issues associated with the question of what content to drop and what to include. Some of the changes in content were obtained from changes in the science curriculum document. Sometimes issues remained unresolved, such as the anomaly of the physics concept of momentum not being mentioned till Level 7 in the physics curriculum, but being mentioned at Level 6 in the science curriculum:

There are other things too, for example some elementary aspects of light, we've actually dropped completely here, expecting it to be taught at Form 3/Form 4 level in science. So that here, there are a few things, we don't mention momentum until Form 6 whereas in the science curriculum they have momentum at Level 6 which is Form 5. So we've got this anomaly of the specialist science don't mention momentum until Form 6 but the general science does early. (Writer 1)

Writers got around the bind of dropping some content that might have value or are the pet topics for some teachers by specifying optional content as well as core content. The optional content added value to the course teachers could teach from the new curriculum in terms of being able to specify other content precisely; not impeding teachers teaching anything of interest to them; and of allowing the tailoring of a course to match different needs of student achievement. The following comment illustrates the value that the writers saw in there being optional content:

You don't have any of this 'could be' stuff in. It's that, that (compulsory content) and that optional. That was a huge relief that that feedback came back and allowed us to go back to that (putting content back into the document). (Writer 3)

6.4.6 Implementation issue: Existing custom and practice

The role of existing custom and practice in the development of *Physics in the New Zealand Curriculum* was specified in the contract between the Ministry and the writers where the curriculum document was meant to reflect and build on current understandings in physics/science education and best contemporary physics/science teaching practice.

Further, the writing brief negotiated for the final document stipulated that the writers had to include a set of content for each achievement level, the writers relied on their experiences of existing custom and practice. The more they thought about what was important in physics, the more they came back to the traditional aspects of mechanics, electricity, heat, light, and nuclear physics:

How deep do we actually teach it? And the answer is that there is custom and practice. ... There are a set of text books written in New Zealand, there are a set of exam papers that have been examined over the last ten years or so, preferably the last five years to look at the more recent ones and you just learn how deep you go by looking at those textbooks. So, in the same way, custom and practice need to be seen to be behind all this anyway. So where we have a set of content here, we are specifying that content in the idea that the previous prescriptions have specified that content. (Writer 1)

As mentioned earlier, the writers did not want to create a document that threatened teachers and made the jump required to make changes seem too large. Where possible they tried to keep to familiar custom and best practice such as in the physics content topics:

We were always told by the Ministry that the major stakeholder is the kids, that essentially what we are aiming for is for effective learning by the kids which I think is fundamentally the best; is the proper thing. But operationally we were also thinking of the existing physics teachers, that it had to be something that they could move to that wasn't too big a jump. So we don't see a huge change in the content for example and people felt much more happy with the curriculum when we specified content; and there is far less debate as to what content is there compared with what had happened in previous revisions of the prescription. (Writer1)

In a way, we wanted to try and sell this stuff so we didn't throw teachers in a panic. We wanted them to see familiar stuff; we wanted them to recognise familiar stuff so they didn't feel like they've got to go and change everything. (Writer 2)

Writer 3 mentioned that while the writers acknowledged existing custom and practice, they had to go beyond its bounds. That was something they found that teachers had a great deal of difficulty doing:

In trying to get out of teachers what they thought would be worth having in a curriculum, existing custom and practice was the biggest impediment because they couldn't see beyond it. And you would go to people and say, "Look, we're designing a new curriculum, you know building it up from scratch from the ground up. What do you reckon we should have in it?", or "we're thinking of putting this sort of stuff in it, what do you think?" And they would say, "Oh you can't do that" and you'd say "why not?" and they'd say, "because it's not in Bursary" and you'd think "what the hell am I dealing with here?" You know, but we're talking about re-writing it you know and if we put it in, it will be in Bursary". "Oh no no you can't do that". And so they couldn't see beyond existing custom and practice, and basically anything that differed from existing custom and practice was unacceptable. And that was the sole criteria they used for whether anything should be in the new curriculum, so we found that really quite a disappointing aspect that people couldn't think of what could possibly be better. (Writer 3)

Writer 3 went on to discuss the extent of change to existing custom and practice that is possible to incorporate into a new curriculum document whilst keeping it still viable as a working document for the teachers. This was an important issue for the writers:

Then there was the other problem of existing custom and practice: what if you write a curriculum that is too different from existing custom and practice. Then it will be rejected because it will take too big a shift for people to adapt to it. So what do you write? Do you write a curriculum that is only incrementally different to the existing custom and practice and hope that they write another one in a few years time and eventually you end up with a better one, but how do you know that it won't be worse? Existing custom and practice is done on a shoe string budget so what do you do, write a curriculum that can be taught with the expenditure of no money? Because currently they have no money to spend. Or do you say, "this is what the physics curriculum should be, now fund it." And that was a difficult question. (Writer 3)

In the end, the writers wrote a curriculum that they would like to see implemented. In doing so, they had to live with the knowledge that the impact of what they had written could be eroded by existing custom and practice. The writers' knowledge of this situation is reflected in Writer 1's comment on teachers' consideration of the pedagogical elements in the draft curriculum: "Oh! Teachers ignored all that and they just go on to the content."

6.4.7 Implementation issue: Derive teaching schemes from curriculum document

At the time of writing the curriculum, there had been recent major organisational and philosophical changes in the nature of schools in New Zealand with schools becoming more autonomous. This was a consequence of the adoption of the *Picot Report* and *Tomorrow's Schools* (Department of Education, 1988b, 1988c) where the focus was on educational administration reforms leading to self-governing schools. The writers saw the physics curriculum document as a framework that could be used for developing individual school's physics curriculum. Thus teachers were expected to develop their school's curriculum for their students from the curriculum statements. The writers feared that teachers were not prepared or trained for that; they were used to Ministry doing it for them in the age of the Department of Education. They even argued that teachers may not want to do that:

Yes we worried not so much about how students would respond to it, but how teachers would use it because we were told teachers would use it to construct their own schemes within their schools and this was at odds with conventional curriculum which teachers would just use to teach from, ... I mean, it's constructing their own scheme within their school, all that consisted of in the past was saying, "Oh well the curriculum is there, I think I'll do topics 1, 2, 3 and 7 in Term 1 and that was them creating their school scheme. They didn't have to actually make any philosophical decisions, it was just timetabling; I'll do this topic because it is winter. But this document is actually calling for people to make much more far reaching sort of decisions ...; what they wanted to do was give teachers a sort of a philosophical framework and to go construct basically their own course and that was a far more demanding thing which teachers frankly didn't want to do, and you can see that by the way they are responding to it now. If you give them that content they will just grab it and go. They don't want to really have to make up their own courses.
(Writer 3)

The writers were aware that *Physics in the New Zealand Curriculum* demanded greater local adaptation and the choosing of possible learning situations by teachers. They realised that there was a certain amount of difficulty associated with doing that but claimed that their intention in developing the curriculum document was to provide such adaptability:

So when a teacher looks at this, and this is where it comes into the implementation, that's going to take a lot of reading, a lot of thinking. We're not wanting people to slavishly do those examples. (Writer 1)

I don't know why we should make it so easy for teachers; because they are not meant to pick this document up and say "right now I'm going to be teaching this". They are actually meant to use this and design their own learning programme to suit their particular modes of teaching and the students that they've got. (Writer 2)

6.4.8 Implementation issue: Inadequate curriculum development

The writers considered that the curriculum development process was one that was curtailed with regards to the successful implementation of the curriculum document. In particular they identified how what they wrote was not really trialled. Furthermore, the writers identified the need for a Teachers' Guide to help teachers in the process of developing their own curriculum. Writer 2 lamented that the final curriculum document published for schools was only in the development stage of a final draft document. It needed further trialling before it was to become a final curriculum document:

Spend money, have an adviser, trained adviser, one of those or someone like who was trained to go round and give guidance to other schools, or small areas, the workshops, and money for a teaching guide, and resource development. I was going to write a book for this. ... Well you see we wanted, again the best way to do it, the government want a particular way of doing, of teaching, but they are not actually modelling their own method. Why put this (the document) out without trialling it? ... I mean I look at it now and I think "oh yea god, did I do that, yea" And but it's only with feedback after using the document. And that's what I really feel sad about, is implementing something without these trials. We said that another thing we need were resources, teacher development, people actually appointed to go out and do that teacher development, that's their full time job. Those kinds of logical things got cut off. So that's sad, really, you know, because you always feel responsible in a way because people are going to judge this by how they use it, when in actual fact this is like draft two, this should be the final draft. This is the preliminary one, people made comments, this came out (the curriculum document), this should go for trial and then a final document.
(Writer 2)

Writer 2 went on to compare the professional development put in place for the implementation of Unit Standards suggesting that similar methods would have been good for the implementation of the new physics curriculum as well:

You see all the money has gone into the assessment. There was heaps of money for Unit Standards, there was development workshops, there are moderators in place, there is professional development going on, between providers and moderators. That's the one positive that has come out for all the schools, the contact they have with another physics teacher and the chance to

talk and discuss. That's the real positive that is coming out of it. And all the money is going to that so why not put money into this and have advisers who have been trained in this, so they're a phone call away or someone will write their scheme and send it to their adviser and their adviser will look at it and discuss it. Yea that same model that QA are using for their Unit Standard assessment, why can't the Ministry do that for this curriculum change, they won't put their money into it. It needs a Teacher's Guide and we were writing this with the idea that there was going to be one. That's very sad. (Writer 2)

As with Writer 2, Writer 3 would have liked the curriculum development process to be a bigger, appropriately funded undertaking that provided teachers with guidance in how to develop the classroom curriculum.

Disband NZQA (laughter). That's all what's needed. ... Yea, put a bit of money into physics education, put a bit of money into training physics teachers, develop teaching guides which are drawn from examples of really good teaching practice. (Writer 3)

6.4.9 Summary of implementation issues

The writers, being teachers themselves, were aware that teachers would not automatically take up *Physics in the New Zealand Curriculum* and change their classroom practices. They were aware that the new curriculum, with its movement away from teaching based on the examination prescription, was a move away from existing custom and practice. The writers felt comfortable with the notion that they were asking teachers to move from their comfort zones, although the issue of whether teachers would change if the move indicated in the curriculum was too big was also mentioned by the writers. However, the issue of inclusion of content did move the curriculum towards familiar practice. A number of other issues arose for the writers because the curriculum they wrote was breaking new ground for physics teachers, such as the suggestions for the utilisation of a contextual pedagogy and the inclusion of the societal aspects of physics. The writers were unsure how successful the curriculum change would be and they questioned the resourcing and process of curriculum development.

6.5 Conclusion

There were a myriad of issues and debates that arose in the course of developing the curriculum. These have been loosely cast into the categories of political issues,

writing issues, and implementation issues. Within the political category, there were issues that were concerned with the ideologies and imperatives of the Minister and the Ministry of Education, other government agencies, special interest groups, and the writers themselves investing their visions in the curriculum document.

There were complex issues dealt with by the writers as they engaged in the writing process. A number of these issues arose from the constraints derived from the subtle politics that prescribed the writers' brief. The writers often described the issues in terms of the many decisions that they had to make: developing aims and achievement objectives that fitted with the curriculum structure they had been given to work with; ensuring that aspects that they as physics educators regarded as important were incorporated; avoiding the curriculum being a prescription and at the same time providing a document that supported pedagogical change.

While external political issues impacted upon the written document, also important in the construction of the final form of the document was the anticipation by writers of how the document would be seen relative to "existing custom and practice". They could see that some teachers would not move easily from what current practice was and would have difficulty envisaging pedagogies and teaching schemes different from what currently existed. They also knew that if the curriculum specified directions too dissimilar to that which currently existed then teachers would reject those directions. They saw the development of a curriculum document that was essentially a "curriculum as framework", for teachers to develop unique teaching schemes, as potentially empowering for teachers. However, a major issue was whether teachers, without further guidance, would embark upon changes in the directions that the writers intended. What runs strongly through the considerations of the writers was their awareness that the community of physics teachers might not necessarily take up the physics curriculum as intended by the writers. The writers could see that there were competing ideas (about the importance of content, about the value of teachers' current practices, about assessment and exam prescriptions) which could undermine the uptake of the elements of *Physics in the New Zealand Curriculum*. In the terms of Wenger (1998), the curriculum document was a reification of certain cultural objects of value, but as was realised by the writers, it is through participation that the cultural significance or meaning of the document would be negotiated by the teachers.

Participating in an activity that has been described is not just translating the experience into embodied experience, but renegotiating its meaning in a new context. (Wenger 1998, p. 68)

The attitudes and desires of the writers remained steadfast throughout the project but they realised that there was need for help in professional development to materialise their vision of *Physics in the New Zealand Curriculum*. Unfortunately, by the time of the interviews, they were beginning to feel that funding and Government commitments to Unit Standards were starting to curtail realisation of some of the goals that they had set out to achieve in writing the curriculum.

So far this thesis has looked at one side of the coin of curriculum change - the development and dissemination to teachers of *Physics in the New Zealand Curriculum*. The other side of the same coin in this curriculum change process encompasses the experiences and issues involved in the implementation of the new curriculum. The stage is set to study the experiences of teachers as they attempted to implement the new physics curriculum in their schools and classrooms. The results of this exploration is presented as two case studies of physics teachers in Chapter 7 and a summary in Chapter 8 of comments by ten physics teachers involved in the implementation of this new physics curriculum.

Chapter 7 ➤ Case Studies of Two Teachers

7.1 Introduction

In the last two chapters, the writers of *Physics in the New Zealand Curriculum* expressed their experiences, views, ideas and concerns. These were related to the development phase of the new curriculum document. This chapter and the next are devoted to the voices of ten teachers who were interviewed regarding their thoughts and experiences in the implementation phase of the new physics curriculum. The three sets of interviews conducted for each teacher spanned their views before the mandated year of implementation, during the first year of implementation and their reflections after one year of implementation. A vast array of opinions was voiced by the teachers and the range of comments from all the teachers will be dealt with in the next chapter.

This chapter is devoted in particular to case studies of two teachers, Brian and Cathy (not their actual names), where a fuller picture is revealed of their experiences during the implementation of the new physics curriculum. The data provided here reflects the particular reality of these individual teachers. Some researchers have suggested that case studies such as the two presented here are of limited value as generalisation of case study results cannot occur. This issue and other aspects of case studies are discussed in Chapter 4, section 4.2.3.

The two teachers were chosen to be presented as case studies because they showed different affinities to the ideas advanced in *Physics in the New Zealand Curriculum*. They were both very experienced teachers with different educational and teaching backgrounds, and they also had different attitudes and aptitudes in physics education. Brian was a physics teacher with a chemistry background, and Cathy was a physics teacher with a physics background and experience in teaching Nuffield Physics. Brian was a very capable hands-on person, and Cathy was not confident doing physics activities that involved hands-on work or computers. Studying their contrasting approaches to *Physics in the New Zealand Curriculum* has the potential of providing valuable insights into the area of teacher change within a curriculum change process.

Once again the data collected to study the implementation phase of the new physics curriculum was derived from the insiders' perspective (from physics teachers who were involved in the implementation). A series of three in-depth focused interviews spanning experiences over three years or more accumulated a vast quantity of data. For the case studies of the two teachers, the data was placed under six categories with descriptive headings that reflected the focus of part of this research, in particular, research question 2 (see end of Chapter 3) about teachers' interpretations of *Physics in the New Zealand Curriculum* and their interactions in its implementation. The data was categorised under teachers' backgrounds, starting points and beliefs; professional development associated with the new physics curriculum; their views of the curriculum document; how they designed their new teaching programmes; their needs for implementing the new physics curriculum; and their perceived changes in practices and beliefs. These categories comprehensively covered the processes and issues involved for teachers implementing a new curriculum. The subheadings within these categories are merely used to guide the reader. They may be different for Brian and Cathy as they reflect the particular themes of their interview data. The case studies are written up as *Brian's Story* and *Cathy's Story*.

7.2 *Brian's Story*

7.2.1 Brian's background, starting point and beliefs

Background in teaching:

Brian was a very experienced teacher who was the head of his school's science department. He had 18 years of experience at his present school and about 27 years of teaching in all, but only 18 years of physics teaching. He had majored in chemistry but had completed stage two physics papers at university. During the period of the curriculum implementation, Brian was very busy as he was involved in extra administration work.

Background in learning:

Brian described how, when he was at school, he had a very inspiring teacher who was friendly and open. This teacher taught him PSSC (Physical Science Study Committee) Physics, a physics programme that was widely used in New Zealand in the '60s and

'70s where there was a move away from physics being presented as a body of facts to an inquiry approach where "men (sic) seek to understand the nature of the physical world". They shared similar views and Brian found him interesting. He remembered one lesson where they talked about photography the whole period, instead of any formal teaching, and it left him with good memories. He incorporated such ways of digressing and being informal and friendly into his own teaching style. There were others amongst his early physics teachers who were inspirational, although he said that his university teachers were not.

Starting point:

Brian described himself as a friendly but authoritative person who likes things structured. He suggested that there is efficiency in the teacher directing a discussion or the course of a lesson. He expected students to be attentive and listen actively when appropriate. He described his teaching style as involving quite a lot of talk and chalk, a lot of questioning, overhead projector use, workbooks, lots of demonstrations and practicals. He described himself as more traditional than the newer breed of teachers as he did not include small group and whole class discussions and debates in his lessons. "I still see myself as someone who directs the kids."

While he thought his style of teaching was somewhat teacher-centred, he thought that the students seemed to enjoy his lessons and could relate to his examples. "I believe I am flexible to cope with whatever they throw at me." He said that he built on the interests of his students by using pertinent examples. He was aware of the more student-centred styles of teaching but emphasised that when one has been teaching for a long time, one develops a tried and true way of teaching.

Brian said that he used to teach from the list of content in the exam prescriptions. He saw that the driving force for students who take physics as a subject was to sit the Physics Bursary exam. He was quite happy with the present exam system as he had worked in that system for a number of years. He pointed out that students wanted to know the content as that is what is assessed in the exams.

Beliefs about assessment:

For Brian, the role of assessment was to indicate where the students are at, how effective the teaching was, and for students to become aware of what they do and do

not know. It was also an indicator to parents and other people of a student's achievement in relation to other students. It was a means of getting into the mind of the students in terms of their knowledge and understanding. Thus Brian saw assessment as an essential and a natural part of the teaching process.

Beliefs about physics:

Brian described physics as a body of knowledge. He liked the logical and the mathematical aspects of physics. He saw physics as being more precise than chemistry as it can be tied down to nice tight explanations of phenomena which he found much easier to grasp. He said that he barely touched on the provisional nature of physics knowledge as he thought that a lot of the physics they do was related to fairly well established phenomena with definite explanations. "I think the body of knowledge that we deal with is pretty well hard and fast."

For Brian, physics stood as a subject in its own right and its method of thinking had applications in a wide range of areas. He felt that aspects of physics learning remain with the students and have relevance to the students' future endeavours, not merely in the training for future physicists or for university physics.

Beliefs about being a good teacher:

For Brian, a good teacher was someone who gained the confidence of students so that they could get assistance any time, conveyed information and knowledge in a clear way, was friendly and approachable, and was sympathetic to the needs of individual students. They had to be knowledgeable or know where to get the information, be innovative, prepared to try different things, not to get stuck in the rut doing the same stuff year after year, keep up-to-date, have a sense of humour, be aware of where students are at when they ask questions, quickly understand their difficulties and address them efficiently.

Brian described himself as a "fiddler". Initially this was with hi-fi equipment and later with computers. He thought that being a practical person is important for a physics teacher.

Beliefs about good teaching:

Brian thought that a teacher would not be able to cater for all the learning styles of their students. "You can't be everything to every person all of the time." He would go

alongside the few students who were having difficulty in class and try alternative approaches.

He also felt that good teaching occurred when there was a good classroom atmosphere, positive students interested in what the teacher was saying, and not “chatting away among themselves”. In such a classroom, the teacher presented work clearly, had a neat attractive environment that was interesting with good physics equipment and posters. Experimental work would be done regularly and there would be practical demonstrations, discussions and interactions between students and teacher. Thus for good teaching to occur, Brian felt that it was paramount for the teacher to know their subject well: “important to know your stuff well and have a good depth”.

Beliefs about learning:

Brian saw learning as building up a “jig-saw” picture. Learning was by looking, listening and doing. He suggested that students required the physics knowledge to be accessible to them, and then be able to apply it in problem-solving situations. He saw practical work as essential as it puts the content into a practical situation to make sense to the pupils. He stated that “you’ve got to use their existing knowledge and experience ... otherwise you are working in a vacuum.”

He believed in getting students to do things with equipment because it is there that they came up against the “real” physics, rather than just the teacher talking about it or demonstrating it. It was his hope that such a hands-on approach would enthuse students to do physics and carry on studying it, though he acknowledged that many do not carry on in physics. He believed that plenty of experiences in the laboratory are good as students remember them. For him, physics was real applications in very interesting practical situations. “I am a hands-on person. I don’t believe in theory all the time; it is not my style. I am a person who is very much into seeing the physics, actually doing it rather than trying to describe it on the (black)board.”

Beliefs about race and gender in physics learning:

He felt that the low representation of Maori and Pacific Island students in physics classrooms was because they probably didn’t have the aspirations and the study skills,

and were unsupported at home. He saw support as very important. He also questioned whether Maori and Pacific Island students saw the relevance of physics.

He thought that girls might not take physics because of the topics which some teachers select. His view was that girls have a different nature and are more interested in relationships with people rather than with objects. His top student was a girl but her nature was described as quiet and highly focused, “not a bubbly friendly sort”.

7.2.2 Professional development associated with the physics curriculum

Brian reported that he did not attend the initial physics curriculum teacher development sessions because he attended the chemistry ones. However he did attend subsequent physics professional development sessions the year before he actually implemented the curriculum. One was on Unit Standards assessment and the other was on the new curriculum and writing schemes of work. The Unit Standards course revealed the huge amount of workload required to conduct standards based assessment and so Brian was not too keen on taking on Unit Standards. The course on the new curriculum was run by a teacher and Brian found it good because of the presence of other physics teachers: “It is good when physics teachers get together and talk and share ideas and see what other people are doing.”

In the first year of implementation of the new physics curriculum, Brian attended a teacher development day that he found useful because he felt that it was time set aside for teachers who were in the same boat grappling with new emphases in physics education to discuss things: “We don’t always have time to think on our own because we are too busy. Time out with other physics teachers is good, very valuable.”

7.2.3 Brian’s views of the curriculum document

Initial impressions:

In the first interview, Brian reported that his initial impression of the curriculum document was that there was an attempt to relate physics to everyday experiences. However he found it rather vague and open to interpretations. This he supposed was because it was designed to give teachers the chance to develop ideas along their own

natural interests. He mentioned that a danger of such an approach was that students might get a one-sided overemphasis on certain topics.

Brian reported that during initial implementation, the curriculum document was not considered to be particularly important for him. The curriculum document sat on the shelf and was pulled out occasionally. He said that he did not find it inspiring and so did not really think much about it.

About the objectives:

He reported that he felt the list of objectives in the new curriculum demanded a completely different mind-set. His way of teaching was to bring everyday examples into topics taught in physics. He suggested that the new curriculum would require him to start with everyday examples and then look at the physics ideas in a particular context. He was not comfortable with that: "I find that a little bit messy."

In the first interview he said that he thought that Achievement Objective 2 could be covered by the two assignments that he usually gave during the course of the year; one dealing with historical development and the other dealing with contributions of a particular scientist. He thought that this objective was not new to teachers as they "have been doing that for years".

Brian viewed Achievement Objective 2 as involving society and physics. He was not assessing it during the first year of implementation. He thought that aspects of Objective 2 such as ethical concerns lie within the realm of social science and not in physics. He saw physics as fundamentally concerned with Objective 1 dealing with concepts, principles and models, and Objective 3 dealing with experimentation and investigations, rather than Objective 2 which he interpreted as the human face of physics. For him, Objective 2 was catering for the less able physics students, "not hard scientists".

Using contexts:

In the second interview (during the first year of implementation), Brian indicated that he did not find the suggested learning contexts in the document personally useful as he had his own ideas and so he felt that he did not need any more. He had found that

the suggestions in the document were things he had been doing all along, so nothing was different or new to him.

He reported that his approach to using contexts was not one of using them as a starting point to his teaching. He said he did not like the given suggestion of sample contexts such as “household technology”; that it was too wide and he was left wondering where to start. He said he preferred working from theoretical concepts to contexts or applications, rather than the other way around.

Reflecting on the place of contexts, he felt that when students got the basic ideas and background knowledge, only then would he bring in the contexts at the end of the course. Otherwise, he stated that he still did not think contextual teaching is an efficient way of teaching. He claimed that the exams still break questions up into different sections and did not bring everything together in one context.

Idea of levels:

As for the idea of levels in the document, Brian interpreted it as corresponding to class levels. Since there was no fifth form physics (Year 11) at his school, he taught topics at both Levels 6 and 7 to his sixth form (Year 12) physics students.

Role of content:

At one stage, midway through the first year of implementation, Brian said that he had no problems with the content. To him, the content formed the main physics education guidelines and the objectives formed just a subsidiary framework. However, in the final interview, Brian highlighted that there had been some interesting and fascinating topics left out of the prescribed content.

Final views:

Reflecting at the end of one year of implementation of the new curriculum, Brian raised issues about the generality of the description of the purpose of physics education. He saw some of the aspects of the curriculum document as very general especially that of “exploring and observing physical phenomena” for investigations. He concurred with the values underlying the investigative skills, but pointed to the generality of the whole curriculum and of the essential skills stated in the document.

In the final interview, Brian restated that he did not refer to the physics curriculum document very often. The document was not a source for his scheme of work, but when he looked at the document, it confirmed that he was doing the things suggested there. “I am covering that but through what I have always done.” He suggested that at present for him, there were too many documents to consider: in physics, chemistry, and technology. He said that he relied on other physics teachers to give an interpretation of the document and went along with that.

7.2.4 How Brian designed his new teaching programme

Initial feelings:

In the interview prior to implementation, Brian expressed a number of misgivings about designing a programme for the new physics curriculum. He was uncertain about whether he was covering all the topics in the new curriculum. He was confused about how he would plan the new programme as there was a need to correlate the curriculum framework with the qualifications framework. He was also wondering if he needed to incorporate some Unit Standards.

Because of these design issues, Brian had delayed setting up a new programme at the time of the first interview. He said that he felt that it was possible that in his current practice he was already teaching to the new curriculum and so he might not have to change his school scheme too much. He also said that the presence of the list of content given in the document could be used to generate the teaching scheme even without application of the achievement objectives stated in there.

Developing the new teaching scheme:

In the interview midway through the first year of implementation, Brian described how he had worked together with the other physics teacher in his school to write up a new school scheme for physics. That had been submitted to the New Zealand Qualifications Authority (NZQA) and was accepted. To write it, at first they had looked at guidelines given in the new Bursary and Sixth Form Certificate exam prescriptions as to what needed to be included. Then they had worked out the assessments with a couple of Unit Standards to be trialled at 6th form (Year 12) because Year 12 was totally internally assessed. They had not included Unit Standards

for 7th form (Year 13) as they had the external Bursary exam and felt that they did “not need the extra pressure”.

In developing the new teaching schemes, they had looked at his old schemes that had been refined over the years and had checked how the new exam prescriptions for Bursary and Sixth Form Certificate fitted in. Most of the practical work had been based on the old CDU (Curriculum Development Unit) booklets. They had not had access to a sample teaching scheme developed by a group of South Island teachers based on the new physics curriculum at that time. Neither did they use textbooks to plan the scheme. Brian reported that for him and his colleague, writing their physics scheme was not too difficult as they had been “in the game long enough”. They had focused on the content and then tried to bring in the achievement objectives. “I saw the content as being that ... that’s your physics. This (the objectives) is just a framework into which to put these things (content).” They had kept their scheme quite open as to the specifics of the content but it had a more defined statement of experimental work.

Final reflections:

In the final reflections interview, Brian reported that the implementation year in physics had gone well and he was pleased with it. Everything had basically run to plan and he had kept within time schedules. He thought that the external Bursary physics examination had contained no surprises and the students who had worked hard had found it good. He had marked the students’ manuals only once during the year due to lack of time. That was something that he wanted to change in the following year.

Brian reflected on how he usually went into his classroom with minimal preparation, having done it all before so it was all “up in his head”. He said that he did not refer to the physics curriculum document as he knew what changes there were in it.

7.2.5 Brian’s needs for implementing the new physics curriculum

Perceived needs:

In the pre-implementation interview, Brian suggested a number of resources that would be helpful to a physics teacher implementing the new curriculum. Brian

perceived the list of content that was included in the final curriculum document was useful as it gave teachers something to hang on to. His ideas for further resources included teachers' guides, groups of teachers developing teaching programmes for the various topics and sharing this around all the schools, experts to write documents in simple terms on their specialist topics such as telecommunications, having samples of special topics, and reviews of existing teaching packages on various topics about their aptness for the different levels at school.

Need for time and support material:

In the initial interview, Brian suggested that he would like some support material to enable teachers to slot changes in easily. As for himself, Brian said that he would need a block of time to analyse and develop a school scheme to implement the new documents. "...the major need is time out to have a jolly good think about it without all the constraints from day to day teaching." Because he taught across a variety of subjects, each with its own new curriculum document, and there were assessment changes happening at the same time, this placed a lot of pressure on his time. Brian suggested that school camps and other administrative tasks left him very little time to attend to the changes required by the new curriculum.

Need for assessment resources:

In the year of implementation of the new physics curriculum, Brian started teaching a new course called Electrotechnology. There was staff funding for that course and there were prepared and moderated Unit Standard assessments for it. In the interview during implementation, Brian commented that without those already prepared and moderated assessments, writing fresh assessments from scratch would have been an immense amount of extra work. He suggested that having similar resources for the new physics curriculum would have made its implementation much easier.

Need for discussion with other physics teachers:

In the reflections interview at the end of the first year of implementation, Brian stated that he felt a need to get together with physics teachers to discuss the different emphases in the physics course. He found that going to conferences and talking to other physics teachers was helpful to him as a teacher.

7.2.6 Brian's perceived changes in practices and beliefs

No change:

In the interview during the first year of implementation, Brian thought that he had made no change in his style of teaching 7th form (Year 13) physics. He considered that he had already found tried and true ways of teaching physics and was not prepared to change. He had not looked at the content in the curriculum much because he believed that the changes were fairly minor.

Brian suggested that he was basically teaching the physics course much the same as he always had. He was even continuing to teach content that had been dropped or made optional such as thin film interference. He did not feel that he needed to change his teaching approach because he considered that his hands-on method of teaching fitted in well with the document.

Brian said that Objective 2 (developments in physics and influence of society) came into the special topic study of medical physics (a topic he had previously included) so he was not incorporating any further changes related to this new objective.

Brian also reported that he had not done any open-ended experiments with the students in the year of implementation, as he was not organised enough at the time it was scheduled. He considered that this was a step backwards with respect to incorporating the new curriculum compared with what he had done in the previous year.

Minor changes in marking experiments:

He reported that he did not do experiments any differently but that with the new criteria for assessing practical work, he was marking practical reports differently. Whereas he used to blanket mark everything he now picked aspects that satisfied the criteria outlined in the curriculum. Apart from this small change, he considered this year was the same as any other year. At the end of that teaching year, he was anticipating that the following year would be much the same. He was also quite adamant in stating, "No, I haven't changed, no".

Anticipated changes for the future:

Looking ahead to the next year, Brian identified a number of changes that he intended making. These included more organisational changes, more structured assessment, and marking the students' work a bit more (e.g., their manuals). He said that he was also planning a few refinements in the experimental area such as employing new equipment, and using the data logger equipment.

Brian said that there were to be school-wide changes in their reporting systems next year with comments on practical skills going to be incorporated in the physics reporting format. He said that he would look at incorporating some other aspects as well. He was wondering whether to include an exam mark in the report. He considered that parents often like having exam marks and that these were good for the better achieving students but not so for the weaker students.

7.2.7 Summary of Brian's views

Table 1 contains a summary of the main features of Brian's views related to *Physics in the New Zealand Curriculum* and its implementation. 'Pre-implementation' views mainly comprise his ongoing views about physics education until 1996. (He had at this time only a cursory knowledge of *Physics in the New Zealand Curriculum*.) 'Post-implementation' views refer to his views on *Physics in the New Zealand Curriculum* after the first year of mandatory implementation of the new curriculum in his classroom in 1998. (The post-implementation column of this table will be contrasted in the concluding section of this chapter with the corresponding features of Cathy's and the writers' views.)

Throughout the first year of implementation, Brian felt that he was teaching using his tried and true methods in physics. In relation to the influence of the new physics curriculum on his pedagogy, Brian remarked, "No, I haven't changed." However he did make a minor change to the way he assessed experiment reports using the criteria set out in the curriculum document. He had plans to change some of his teaching practices for the following year but these changes were not driven by the curriculum document.

Views about Curriculum	Pre-Implementation Views (about his current teaching scheme)	Post-Implementation Views (about <i>Physics in the New Curriculum</i>)
<i>Philosophy</i>	Physics is a body of knowledge derived from the scientific method. It involves theory and applications in practical situations (generally in the laboratory).	The philosophy of the new curriculum is to relate physics to everyday experiences; but this is too vague and open to different interpretations by teachers.
<i>Achievement objectives</i>	Objectives maximise external examination outcomes, therefore content is of utmost importance. Objectives also include hands-on practical experiences with equipment so as to enthuse students and make physics learning memorable	Objectives on physics concepts and investigations considered as core physics. Objective on 'physics and society' not essential. Require a different mindset to teach from these objectives. Objectives used only as a check whether teaching scheme complies with document.
<i>Learning contexts</i>	Did not use contexts except as applications after teaching concepts, because his teaching sequence started from theory, then laboratory experiments and examples.	Did not find suggested contexts useful. Deriving physics from contexts not used because it is "messy" and not an efficient way of teaching physics.
<i>Assessment</i>	Used tests, examinations, and summative grades on laboratory reports.	Concentrated on formal tests and exam assessments rather than new curriculum assessment examples. However, utilised new criteria of investigative skills when assessing practical work.
<i>Physics and society (achievement objective 2)</i>	Taught a medical physics module as an example of social application.	No changes made for this new objective. Used medical physics module previously taught. Felt notion of 'physics and society' caters for less able physics students.
<i>Contents</i>	Obtained from exam prescriptions.	Contents considered the main aspect of the new physics document. Teaching scheme can be generated from contents only, without regard to achievement objectives.

Table 1: Summary of Brian's views about the physics curriculum (pre- and post-implementation of *Physics in the New Zealand Curriculum*)

Table 2 shows Brian's substantially unchanged global beliefs about physics education and the whole implementation process, despite the change influences acknowledged by him. The forces for change were related to assessment initiatives and technological innovations. Moreover his perception of the limitations of the contextual teaching

approach (based upon his negative experiences in using it in chemistry) was a force against making a similar pedagogical change in his physics classroom.

Beliefs/Change Influences		Brian's Views
Fundamental Beliefs	<i>Nature of physics</i>	Physics is a body of knowledge that is logical and mathematical with precise explanations of phenomena and technological applications. It does not include the provisional nature of physics knowledge as physics at that level is “pretty well hard and fast”.
	<i>Learning</i>	Building up a “jig-saw” picture. Learning occurs by looking, listening and doing. Learning needs physics knowledge to be initially acquired before it can be applied in problem-solving.
	<i>Pedagogy/practice</i>	Teacher-centred method effectively conveys knowledge via exposition, demonstration and discussion. Main focus on content: theory taught first, followed by practical; experiments are important. Emphasis on theory and scientific method leading to passing exams.
Change Influences	<i>Professional development</i>	Did not attend initial physics curriculum development sessions, but did attend sessions on unit standards and writing schemes of work. Appreciated time to think and share with other teachers.
	<i>Implementation needs</i>	Resources such as teacher guides, teaching topic packages. Opportunities to meet with other teachers. Time to plan.
	<i>Implementation planning</i>	Designed new school scheme based upon existing teaching scheme, exam prescription, and practical work units. Ensured that content matched new curriculum then cross-checked that the scheme related to the achievement objectives.
	<i>Current change</i>	“No, I haven’t changed.” However utilised new criteria for assessing practicals.
	<i>Openness to further change</i>	Planned future changes unrelated to directions of the new curriculum, i.e., organisational changes, structured assessment, more marking, using more computerised equipment and new reporting system.

Table 2: Summary of fundamental beliefs and change influences for Brian.

Brian’s case illustrates that for a very experienced practitioner with a particular pedagogy that they viewed as effective and consistent with their views of teaching, learning and the nature of physics, no change in belief or practice may occur within a curriculum change situation. The generality of *Physics in the New Zealand Curriculum* legitimised Brian continuing to teach physics in traditional ways.

7.3 Cathy's Story

7.3.1 Cathy's background, starting point and beliefs

Background in teaching:

Cathy was a very experienced teacher who was the head of her school's science department. She had about 20 years of physics teaching after having majored in physics at university. During the period of the new physics curriculum implementation, Cathy was very busy as she was the third form dean of the school.

Cathy reported that as a beginning teacher, she started with Nuffield Physics in England. She had not done any teacher training and was thrown into teaching straight after university. She described Nuffield Physics as a "wonderfully set-up scheme" related to everyday life. She said that as a consequence of her Nuffield experience, when she came out to New Zealand, it was a bit of a culture shock to find that physics here was very much more theoretical. She noted that the thrust of the new curriculum had not been such a shock to her as she had always had a student-centred way of teaching due to her early introduction to Nuffield work: "The curriculum now is more the way I have always seen it." Cathy noted that even in her old teaching scheme based on exam prescriptions, she would try to get the students to actively participate as much as possible.

Background in learning:

Cathy stated that she had learnt physics in a very theoretical way and essentially she had been taught to pass exams: "We just sat and listened." She said that she enjoyed her physics lessons as she described her teacher as "an absolute nutcase". Practicals, in her background experience, were done in a very rigid sequence.

Cathy mentioned that her experience of being part of Playcentre (children's preschool in New Zealand) and their way of looking at learning had also influenced her ideas in teaching. Cathy stated that people fascinated her rather than things: "In teaching, it is actually the kids and it's not the subject matter. So while I teach physics, it is actually the kids I am teaching rather than the physics." She believed that the way a teacher teaches is based on their theories about learning.

Starting point – attitudes:

Cathy described her attitude as being not interested in how things work but rather on what they can do. She said that to play with technology was not fascinating for her, but she was happy to use technology to demonstrate effects (e.g., phases in alternating current), because illustrating the theory with the technology was fascinating for her.

She also mentioned that she did not see the point in pulling things apart in a physics lesson to learn about a particular appliance. However, she indicated that this was also due to lack of confidence: “They need to be things that I am confident with myself, ... not going to pull apart a radio ... no idea how that fits together.” She suggested that she would always shy away from pulling technological appliances apart.

Cathy disclosed that she lacked the confidence to have an unstructured lesson. She said that she did not like to be in a situation in the classroom where she did not know the answers to students’ questions, or at least where to look for the answers. She reported that she did her physics degree a long time ago and so she thought that there was a lot of basic physics that she did not remember. She felt that she was “teaching from a level not much above the kids, really.”

Cathy said that she would really like to learn from people who have some fascinating ideas and who are passionate about what they do. She noted that she had not had that opportunity and so she learnt as she went, “a little bit here and there”, and that she tries to adopt other people’s good ideas.

Starting point – pedagogy:

Cathy described her usual pedagogy as involving looking at physics concepts first and then seeing how they get used in various components of appliances rather than the other way around. She said that she tries to link the new physics ideas in with what the students already knew. She noted that such ideas expressed in the document were not new to her. Elaborating on her existing practice, she described it as involving doing a demonstration based on the topic of study; students giving their views of what was happening and having a discussion; then the theory would be taught and notes given at the end of the lesson. Cathy mentioned that as she had a small class in Year 13, there was a lot of class discussion and she got the opportunity to assess their use of physics language and understanding.

Cathy said that she was exam-driven in teaching Year 13 and she suggested that good exam performance was what students were aiming for. She indicated that her existing teaching scheme was written to cover the syllabus given in the prescription for the Bursary exams. She saw the focus of Bursary exam questions as shifting from just being able to do physics problems mathematically to more one of understanding the physics concepts. She felt that it was a good change:

I like the greater emphasis on ‘explain’, rather than just being purely mathematical. I think it is really good that students have to try to put in words what’s going on in their heads. That’s a major problem. (Cathy)

She believed that having an understanding of physics concepts would enable them to be used in different ways and in new situations.

Beliefs about physics:

Cathy described physics as dealing with basic ideas that govern the universe and which can be applied in many situations, “kind of like a blueprint”. She said that in physics teaching, she is looking at these ideas and simplifying them down to the basic core ideas covered in her teaching programme.

Cathy gave a very clear assertion about what she believed to be important in the study of physics: “I still regard the aim of the course is to get certain core content.” She suggested that bringing in examples was just to see physics in real life. Cathy said that she does not use contextual teaching but that she preferred to relate the physics concepts to a lot of real life examples. She preferred this to the more traditional way of using examples divorced from everyday life, for example, body A colliding with body B.

Cathy said that the basic ideas of physics were simple and she used words such as, “the simplicity and the beauty” to describe them. She also remarked on the need to build a unified understanding of physics ideas: “physics is that kind of subject and if you don’t get to that point where all the bits fit together, then it is really unsatisfying.”

Beliefs about learning:

Cathy described learning as occurring when students construct knowledge of something that is relevant to themselves personally. She suggested that teaching was

purely to provide opportunities for the students to build their knowledge for themselves; they could evaluate their ideas in the light of new experiences and keep building their knowledge. Cathy said that knowledge is not given to students. Instead, she suggested that learning needed to be done with other people, in groups, or in a class. She described how understanding occurs in such settings; students come up with their own ideas and then try and match them up with the accepted ideas. The students would all be at different stages where some ideas match up with accepted ones and others don't; then during this process of learning suddenly "it all becomes clear, it all makes sense".

Beliefs about physics learning:

Her aim for her students was to get them to see the main points that govern all of the physical world at a very basic level. She felt that when the simple underlying physics ideas were understood then suddenly all became clear for the students. However, she suggested that there was no point teaching them just the simple ideas directly as "you've got to start with something, ... use that to get to the ideas and then apply them". Cathy suggested that the emphasis on understanding the physics concepts was advantageous: "If you teach from an understanding point of view, it should suit everybody because it is the ideas that are important rather than being able to describe it mathematically." (Nevertheless, Cathy felt that those mathematically able could take it further.)

Cathy reported that she believed that students should be involved as much as possible in the physics lessons and not just sit at their desks in the classroom trying to learn. She said that this attitude was supported in the student-centred thrust of the new curriculum. She also said that she thought that students seemed far more enthusiastic about doing things in the physics lessons that were familiar in their lives rather than the more traditional experiments.

Beliefs about being a good teacher:

Cathy described a good teacher as someone who relates well with students and vice versa; inspires them to find out more; enables students to want to learn and feel empowered to learn; gives guidance and structure to lead students to a particular goal; and gives guidance that is empowering and makes students want to learn. She said

that a good teacher makes the students feel recognised and good about having done the learning tasks.

Beliefs about teaching:

Cathy said that the teacher needs to present their lessons in a progression or sequence of ideas that build on each other and not in isolation as this enables the students to form links between different aspects that they study. She also mentioned maturity as being important for the students to make sensible links. She said that when something does not make sense, revisiting it at some later stage can result in it being better understood.

Beliefs about good physics teaching:

Cathy said that good physics teaching involved a lot of interaction between teacher and students, and among students. It incorporated a lot of debates and activities, not just the pen and paper sort; an opportunity to try a lot of different things and work at their own ideas, not have ideas presented to them initially. Cathy mentioned that what she hated most was a quiet classroom where students were passive, “just sitting there and waiting for something to be given to them, or they are miles away in their thoughts”. “I will be noisy,” she insisted and said that physics should be fun all the way up to senior levels.

Beliefs about teacher authority:

Cathy said that she liked to see the class being productive so she used teacher authority to cut out the messing about. However, Cathy said that she liked students interacting with her and challenging her with their questions. Thus she reported preferring the students to be setting the pace, and asking the questions rather than the teacher doing it all the time.

Beliefs about teacher subject knowledge:

Cathy said that she saw teacher subject knowledge as being really important. She reported that being an older teacher, she had taught for so long that she felt that her physics knowledge had stopped growing. She regretted that but there did not seem to be the same incentive to acquire more physics knowledge as when she was young. She mentioned going to a refresher course or reading about physics as being ways to get back in touch with the changes in physics knowledge.

Beliefs about gender and race in physics teaching:

Cathy spoke about the attitudes of girls, Maori and Asian students toward studying physics. She described how girls expect to fail at physics; that even when they have done well, they think that they can't do physics. She said that there is a perception that physics is too hard and girls think that they have to be very bright to do physics or else they are better off doing something else. She pointed out that this was not an issue with boys as there was a range of abilities with the boys who attempt physics.

She felt that she had to be careful in choosing examples in physics that were girl-friendly and not so theoretical. She said that she would like to see more girls doing physics but even with two female teachers at her previous school, there had not been many girls taking physics. She said that some girls still perceived it as a "how gadgets work" sort of course which, according to her, is not a typical female way of looking at the world. She also noted that there was not good representation for physics from Maori and Pacific Island students but that she didn't know why. As for the Asian students, Cathy said that a more practical emphasis is better for them because they have limited English language. (Her school had a reasonably high number of Asian students.)

7.3.2 Professional development associated with the new physics curriculum

Cathy said that teaching took up a lot of time and noted that as she was also a dean at her school, she did not want too much involvement elsewhere. She felt that her level of interactions with the new physics curriculum at that time was sufficient for her. Cathy did not have any involvement in the production of the new curriculum document. "I was really quite happy for someone else to do it, to be honest." (cf. Shipman, 1974)

In-service courses in 1996:

In the first interview, Cathy reported that there had been two in-service courses in 1996. The first one had been based on *Physics in the New Zealand Curriculum* where they had looked at what they were going to teach in terms of the new curriculum. She had found it really useful. She said that the second one had been more general and introduced Unit Standards. She found that course really helpful too as it showed the

teachers how to use the curriculum document and link it to the Unit Standards. It helped the teachers become familiar with what was on some pages in the curriculum document and suggested a way on how to go about planning their teaching schemes following certain steps. She found being shown a pathway to writing her teaching scheme very helpful for her.

Cathy felt that two such courses a year were really good as there was some continuity and they could build on what was done before. She had also found it “nice” to meet the other women physics teachers saying that “there are few of us left”.

In-service in 1997 - Unit Standards and sample scheme:

In the second interview, Cathy stated that the emphasis in the previous year (1997) had been on Unit Standards (the new standards-based assessment mode being trialled). She reported that during that year there was a big jumbo in-service day run by someone from Christchurch and a couple more days of Unit Standards training. While she was attending the course, she encountered a sample teaching scheme for the new physics curriculum built up by a group of people (in the South Island) which was introduced to the teachers present at the course and she found it invaluable; it formed the basis of her new teaching schemes. She found that it could easily be modified to fit her school. She considered the sample scheme as the best time saving device as it related well to the new curriculum, was clearly referenced and, as it was written by a lot of teachers in her subject area in the same situation, she had faith that the sample teaching scheme correctly reflected the new physics curriculum.

In-service courses in 1998:

At the second interview, that is, midway through the first year of official implementation (1998), Cathy reported that during that year so far she had been to a couple of courses based on the new curriculum. The first course had been on writing a new school scheme in terms of the new physics curriculum which she had found really helpful. She said that it had given her guidance on how to start, where to look next and how to build up the school scheme. She noted that at the course, she had been directed to a lift-up flap in the document that put the physics curriculum for the different levels together at a glance, which she found very useful. As she described it, the course had suggested that the new teaching scheme was to be built up from the

teacher's interests, the students' interests and the content, and that would satisfy the requirements of the new curriculum.

The second professional development course of 1998, Cathy described as dealing more with the philosophy behind the document. She reported how, in that course, physics was seen as an everyday activity, part of the real world and not just a theoretical discipline. This had been suggested in the course to be exemplified by using contexts that were relevant to students.

Usefulness of in-service courses:

Cathy thought that physics teachers getting together reasonably regularly on the physics in-service days had been really useful for her. However, she thought that it was also important for a teacher to work things out for herself as the teaching programmes should suit the conditions at her own school. Cathy said that she was happy to be involved with educators at the local level and talk about ideas. She noted that in her school there were not many physics teachers and it was "nice to work with other people".

Cathy reported that she had found it helpful working in small groups. She thought that small groups needed to be made up of people who work or think in similar ways, to be on the same wavelength, and to have the same priorities about the way they teach. She said that groups interested in computers made her "freeze" and did not work up much interest in her (calling it a "turn-off"). Cathy said that she found hands-on demonstrations at in-service courses were of very short term use. She found that once she was back in her school and the ordered equipment package arrived, she still found it "tricky" to set it up and work it.

While she had found the Physics in-service days usually really good, Cathy also noted that she would have liked short sessions based on looking at just one topic at a time and the sharing of ideas on how teachers have been teaching them.

Informal professional development:

With regard to informal professional development, Cathy felt that she could call on a couple of teachers for help or guidance when needed. There were two physics

teachers at her school but basically they did their own thing and they mainly came together for the purpose of deciding on assessment.

Help from university:

Cathy reported that there had also been liaison with people from university who set up demonstrations with equipment that the schools didn't have, and she had found these to be really good. She mentioned another instance where somebody from the university had spoken about picking up aspects for teaching from everyday experiences. Thus she found that there were "lots of bits and pieces of ideas" available which were very helpful.

Involvement and studying at university:

One major thing for her teaching had been her involvement with an assessment project at the university where they had analysed her teaching. Cathy also mentioned a university course that she had been taking during the year of implementation that gave her a theoretical background for her teaching. She said that she had found the theories of learning and assessment that were taught at the course most fascinating because she usually taught "from the seat of her pants" without these considerations. The course had helped her to clarify her own thinking and formalise it, though she had not made "any great shifts" in her thinking. She also said that she found that the course had helped her realise that ideas put forth by others may not sit well with her as her theories of learning may be quite different from theirs.

7.3.3 Cathy's views of the physics curriculum document

Initial impressions:

In the first interview, Cathy mentioned that she had not studied *Physics in the New Zealand Curriculum* in great detail. She had looked at the headings in the document and thought that the new curriculum had the same kind of emphasis as *Science in the New Zealand Curriculum*, being based on real life situations and applying physics to contexts rather than just teaching physics theory.

Proposed change:

Cathy said that she felt that there was not much change in content. The main change for her was that there was a new way of looking at physics. The change was in the

emphasis, with physics being taught as a useful science rather than as hard theory where one has to be good in mathematics. She said that she liked this emphasis.

Using contexts:

Cathy felt that the document was encouraging teaching physics from contexts. She mentioned a number of reservations about using context in physics teaching including the notion that some ideas were not encompassed by context and needed to be taught separately, and also the danger of teaching from one context all year (e.g., context based around the parts and workings of the refrigerator) rather than a wider physics course. She felt that teaching from contexts could end up with “lots of bits of knowledge missing” and students not being able to put the physics ideas together in a coherent manner. She thought that physics ideas can get lost in the contexts. For her, many contextual situations were not very directed, didn’t lead anywhere, and students didn’t learn much from them. She said that to be fair to the students the teacher needed to build the groundwork of physics concepts first.

Cathy sensed that the document was also encouraging a more hands-on exploration of technological equipment or appliances. While she agreed that physics ideas are used to produce a technological piece of equipment, she felt that dismantling appliances for physics lessons can lead to many separate pieces of information and so detract from the core physics ideas and confuse the students. Cathy said that she didn’t see a lot of point in learning about a particular appliance as she saw the underlying physics ideas to be more important.

Flexibility:

Cathy said that she thought that the new physics curriculum was not prescriptive and so she could tailor it to the way she would want to teach and to what was important to her. “There is enough freedom in there for me to be happy.” She suggested that the emphasis on the aspects of physics and society suggested in the document left it really up to the teacher on how to incorporate that into their teaching programme.

Why there is no change:

In the initial interview, Cathy gave the opinion that even with a new curriculum, she felt that what was actually taught in schools would still be much the same. She suggested that nothing changes because teachers tend to parallel what they already do

in their teaching with the new curriculum and then assume that they are covering all the requirements.

Philosophy of the document:

At the second interview midway through the first year of implementation, Cathy talked about how she had found the summary flap in the Physics curriculum document very useful. She also talked of her interpretation of the philosophy of the document as having a practical orientation. Thus she stated:

Physics is a people-based discipline; discoveries are made in the light of how it affects people's lives. Physics is part of our everyday lives and that is the thrust of how it should be taught. Even theoretical discoveries are turned to useful applications. (Cathy)

Confusion about Achievement Objective 3 regarding investigations:

In the final interview, after the first year of implementation, Cathy reported that she still had some confusion on what was entailed in the second part (part b) of the Achievement Objective 3. She indicated that for her class, the third achievement objective was dealt with by going into the music room and fiddling with the instruments, looking at oscilloscopes and talking about surf waves, etc. However, she said that they did not do practical investigations as suggested in Objective 3b (except an investigation done with a sonometer). She did an investigation analysing motion with a video camera which is also given in the examples for Objective 3b but she said that she did not think that activity should come under that category of objective. She noted that for the optional content, she chose to do only those things that she had done in the past.

Final views:

In reflecting at the end of the first year of implementation, Cathy suggested that she viewed the new physics curriculum document as trying to give an appreciation of physics in our lives by taking some theoretical ideas and using those to look at the world.

Cathy said that she found the combination of the ideas in the physics curriculum document of what is to be taught plus the general objectives as really good. She said

that it was really good to be given the range of possibilities in the suggested examples and that she planned to try some of the given ideas in the future.

7.3.4 How Cathy designed her new teaching programme

Plan of action:

At the time of the first interview, Cathy had not yet designed her new teaching programme. She was initially given the document, *Physics in the New Zealand Curriculum*, and then she attended the first professional development course in the year 1996 where they looked at various aspects of that document and went through the mechanics of planning a physics course. She did not actually plan the course at that time because there was no other teacher in her school to plan it with. She was waiting for the new teacher to arrive. She said that she would be contacting other people and picking their brains when she was ready to design her new programme for teaching physics based on the new physics curriculum. She had found that the other teachers at a professional development course she attended had similar ideas to her and so she would work from those ideas.

At the time of the first interview, Cathy said that she had referred mainly to the last bit of the curriculum document, the lift-up flap, where they summarised the content into levels and the practical skills. She had not looked at the examples on teaching and assessment in the new curriculum. She said that she planned to start from the curriculum document and make sure she covered all aspects mentioned there. She said that she would have to rewrite schemes for Year 12 and Year 13 Physics as their existing schemes are very brief adding, “I am not sure what we’ve got, to be honest; this sounds dreadful, doesn’t it?”

Contexts and content:

As for choosing topics, Cathy said that she would like to include things that she felt were relevant to the students. One example she mentioned as something that she would like to do was the activity on the radio receiver. She felt, however, that she did not have the knowledge to put it together.

Purpose of physics education:

Cathy discussed how for her, the aspect of the purpose of physics education about inculcating enthusiastic learners and good communicators could apply to any subject. She talked of the first three key points in the purpose of Physics Education section in the physics curriculum document, that is, being independent learners, having good understanding of basic concepts of physics, and being skilled practical investigators (see Appendix A5), as being more important aspects in her consideration of the design of her teaching programme.

Developing the new teaching scheme:

At the interview midway through the year of implementation, Cathy described how she had designed the programme that she was teaching. She noted that she had written a new school scheme for Year 12 physics the year before (i.e., in 1997) and had only done the new Year 13 Physics scheme at the beginning of the present year (1998). She based this on the sample physics scheme that was designed by a group of teachers from the South Island and provided to teachers at a professional development training course that she had attended.

Cathy reported that she used three documents to write her teaching schemes: the exam prescription, the sample scheme and the curriculum document which she referred to from time to time. She reported that in using the curriculum document, she made sure she covered all the objectives, but that she designed her programme from the list of the content and the philosophy of the document rather than the objectives.

Cathy said that her new physics programme was not much different from how she normally taught and she thought that it covered the requirements well. She commented that the old scheme was not reflective of how she was teaching and that "... it was a strange document ..."

Assessment and examples:

There were some changes in the requirements for assessment of practicals. She noted that for assessment especially at Year 13, she followed the examination prescription very closely because it spelt out very precisely what the requirements were. She did not use the curriculum document to get ideas for her programme but rather looked at it

for confirmation that they were on the right track. The examples given in the curriculum document were “often things that we already do”.

Final reflections:

In the interview at the end of the year, Cathy reflected that when she had to revise their physics programme, she had merely looked at the curriculum document to compare with what they were already doing and to confirm that she was covering the requirements without actually changing much.

For Cathy, the major difference in the old physics curriculum taught in schools and the new physics curriculum proposed by the document was in the portrayal of physics itself rather than in the content. She repeated, “...there were a lot of things in there (curriculum document) that we were doing already.”

7.3.5 Cathy’s needs for implementing the new physics curriculum

Main needs – time and collegial support:

In the first interview, prior to the implementation phase, Cathy reported that she felt that her main need to implement the new curriculum was to have some planning time. She said that the normal teaching load and normal life did not give much time for developing new schemes for teaching. She said that she would also welcome opportunities to discuss with other teachers, not in big groups like at in-service courses, but in smaller groups of three to four teachers so as to bounce ideas off other people. She said that she had a few people in other schools whom she could ring up anytime for ideas, but she emphasised the need for small group support.

At the final interview, Cathy reflected that she was not happy with how her class of Year 12 went that year (1998) and would put more energy into it the next year. She felt that the course “did not hang well together” and they ran out of time for certain topics. This she attributed partly to the calibre of her students and partly to the lack of her preparation time as she was concentrating on other things: “We just need to sit down and actually work out where we are going.”

Cathy said that she needed a lot of time to develop something in a new way. She felt that extra time needed to be put in by the teachers themselves because even though

there may be other resources “you’ve still got to actually come to grips with it and do it and set it up for your school”. She commented on it being a trade-off between how much time is put in and how much change and benefit can be obtained. Cathy said that she felt that teachers needed time out to do the development of teaching programmes in small groups, just with two or three schools, dealing with basic hands-on things, not the theoretical underpinnings, but developing sections of the course with respect to how to teach certain physics topics.

Cathy elaborated on how she would find it really useful for physics teachers to get together to look at one topic and discuss how they teach it and share ideas. She suggested that it could be just for a couple of hours in the evening. She thought that it would be really valuable because otherwise teachers tended to do things the way they have always done, as they have been successful at it. It would also counteract the isolation of being a physics teacher at her school.

She spoke of the lack of contact with the other physics teacher in her school. Although the other teacher and Cathy had rooms backing onto each other, they rarely actually saw each other because they were so busy. There was a possibility for team teaching but they hadn’t had time to talk about it. She said that they got together only to discuss what they were going to teach and about assessment, and nothing was shared about how they were going to teach it.

Equipment and storage space:

Cathy suggested that having the space to store the physics projects by students which are on-going was important. She reported that although it used to be a problem, they now had the storage space. Cathy said that for some topics being able to share gear was necessary (e.g., for radioactivity, they didn’t have some of the equipment in their school). In this regard, she commented on the university having been a great resource as people were sent out from the physics department to schools to give demonstrations. She also talked of being helped in the past by a contact at the hospital who did some useful demonstrations on medical physics. “It’s just having people who are prepared to give their time for things that we don’t have.”

Diminish the effect of exams:

Exams were another constraint for her as she found it necessary to prepare Year 13 students for the national Bursary exams; so her physics course was quite exam-driven. In the middle of the first year of implementation, Cathy commented on how the Year 12 scheme had been easier than the Year 13 scheme to change in that she had a lot more freedom on how to assess and what she did in Year 12. There being no external exams in Year 12 had made it easier to try the new methods suggested in the curriculum document compared with Year 13 which had the Bursary examinations at the end of the year.

Cathy viewed the exam questions as having more influence in the way a teacher taught rather than the curriculum document itself. She talked of the physics exam questions as having become more context-based and influencing teachers to include more of the physics of real-life situations.

Teaching resource packages:

Cathy suggested that another constraint was the lack of professionally prepared resources to teach the philosophical and societal aspects of physics covered in Objective 2 of the new curriculum document (as additional to the scientific knowledge).

Cathy said that she needed better resources such as topic based resources with background reading and information covering a physics topic and placing it in different contexts. She thought that there would be a huge market for that as there was a big need among teachers. She suggested teaching resource packages with video clips and other supporting materials as very helpful for teachers.

At the end of the first year of implementation, Cathy talked of feeling that teachers didn't have time to get good and suitable activities for the new objectives up and running for their classroom. She thought that for teaching certain aspects of the curriculum like the history of physics, resources such as monographs would have been very useful.

Development of expertise in practicals and demonstrations:

Cathy disclosed that there were certain demonstrations that she would like to do but she did not know how. She said that she lacked the confidence to teach differently using contexts as she felt that she needed more knowledge to pull something apart completely and to get to the underlying physics ideas in that situation.

Cathy mentioned personal limitations as a constraint. She had felt constrained in the area of being able to give an appreciation of physics in everyday lives as she felt that she did not have enough confidence or knowledge to be able to do it. She described her knowledge of electronics as “awful”; that she did not have enough knowledge in nuclear physics to answer some questions; and that she did not have good technological knowledge.

Cathy felt that she needed to increase her knowledge to be able to introduce more applications. She suggested that for her to change much of what she was doing, she needed a lot more familiarity with the technology behind things so that she could use them as examples. She said that she was not sure how to get to that point.

Project work and contextual teaching:

Cathy described how being required to do project work was a real shock to students as it entailed a lot of work. They needed to develop experiments and encountered initial problems and pitfalls with not much success for some. She said that because project work took a lot more time, she would need to be careful that she did not develop the contextual situations in project work at the expense of the physics ideas that are important to be taught. Cathy described a constraint that she encountered when using contextual teaching in the learning context of “physics of toys”. She said that it got too complicated and students did not see the simple underlying physics ideas. She reported that she preferred to use such a context as an initial focus but then get quickly to the basic physics ideas of what makes the toys work.

Changes in content:

Cathy reflected that she was not clear about some of the topics that got shifted about in the new curriculum; somebody had told her that thin film interference was out but she was not sure about it so she still taught it. She mentioned regretting having to give up the topic in future as one of the activities that she had so much fun doing with her class was blowing bubbles for learning about thin-film interference.

Assessment of investigative skills:

In the interview conducted during the first year of implementation of the new curriculum, Cathy reported that she found the assessment of experiments with different percentages for the various investigative skills very difficult to be put into practice. She said that traditionally most of the practicals (experiments) dealt with processing and interpreting results, but with the changed emphasis in the new curriculum, there was a need for students to be planning some experiments themselves. Cathy said initially that there was not much scope for that in her practicals scheme and there was not a lot of time in her programme to include that either. However by the end of the year she had incorporated the planning of experiments as an investigative skill in her assessment of practicals. Cathy mentioned the danger of running out of time as a constraint for exploring investigative skills. She said that she included a lot of activities, such as going outside the classroom and kicking balls, in her programme and that took a lot of time compared to controlled laboratory experiments.

Students' attitudes and abilities:

Cathy said that another constraint that she faced was the attitude of students at her school that it is not important to achieve very highly. She felt that there was a need to convince the students that it was worth making the effort. She suggested that the new physics curriculum required students to be far more involved in the lessons and more prepared to share ideas. Thus, students would need to be more independent in the way they go about learning than they had been previously.

In the interview at the end of the first year of implementation, Cathy again mentioned that a significant constraint to implementation had been the quality of students they had at Year 12. That year she had to teach everything very slowly, ran out of time and had to adjust the teaching scheme. Cathy found when starting a topic, that she had to go back a few steps, and start from scratch as the students in the class had no idea what was being said. She said that because of the wide range of abilities of the physics students, it was difficult to decide on the teaching approach to take; whether to be more general or be more theoretical and mathematical. She reported having tried both ways and so the course that year did not hang well for her.

Cathy said that she had found that students were taking Year 12 physics with very little understanding and background. She attributed that to the fact that students were not getting much exposure to physics concepts in the Year 11 and also to the way science is taught as an exam-oriented course in that year. She said that many students in her Year 12 class had given up on physics that year as they could not understand it and did not make the effort to try and understand it either. She wondered if it was a reflection of what she was doing. She said that she wanted to try and make it more relevant to the students the next time.

Students' background knowledge:

Cathy noted that although the new curriculum allowed teachers to design their own course now at Year 12, basically they were all still doing the same thing as before and the content had not really changed. She suggested that this was because students needed to be led from having very little background physics knowledge to being prepared for the Year 13 physics course.

Summary:

As a final comment, Cathy remarked about the first year of implementation of the new curriculum, "It's gone really well with the physics". She felt that the Year 13 class went much better than the Year 12 class as the Year 13 students were saying that it all made sense towards the end as everything was falling into place for them. "I felt good when they left but I just hope they've done well (in the Bursary exam)." She felt that the Year 13 physics curriculum flowed well as one topic led to the next and the whole programme built up well.

In discussing her needs for better implementation of the new physics curriculum, Cathy spoke of her need for more time for preparation, more collegial support, more supporting teaching resources, and more language support for students with English as a second language as she had quite a number of those students in her physics classes. In terms of supportive structures at school, she needed longer lesson periods as she found the 50-minute lesson periods a bit short at times. She also emphasised the need for a storeroom to keep equipment for experiments that were to be continued at a later time.

7.3.6 Cathy's perceived changes in practices and beliefs

Initial anticipation of changes:

In her discussion in the initial interview, Cathy anticipated a number of changes that would happen when the new physics curriculum was implemented: there would be a greater emphasis on Objective 2 (including the influence of physics on society); she would use context prior to teaching the basic ideas; she would trial some of the NZQA assessments informally; there would be a greater emphasis on students verbalising and communicating their physics ideas, that is, explaining physical phenomena using physics terminology. Cathy described the expected change in the new physics curriculum as making it more context-based rather than just theoretical, but she said that she still expected to end up having taught the same body of knowledge or facts. She said that the change in approach was not too different for her as she taught junior science which was all context-based.

Changes for Objective 2:

One of the changes that Cathy noted was that of bringing in aspects to satisfy the achievement objective to look at the impact of physics on people's lives and the historical development of physics ideas. Although she said that they had always done that in her teaching programme, this year, they would also be incorporating a poster assessment or essay to highlight those two areas.

In the final interview, Cathy reported that there had been limited contextual physics during the year. She did not teach "Sport and Physics" but the Year 12 physics students did go to Rainbow's End (an amusement park in New Zealand) on a field trip and, in another lesson, they had hit different types of sports balls and studied their motion as part of their study of mechanics. Cathy reported that the Rainbow's End visit and the accompanying worksheet were used for assessment purposes, and a poster and an essay were also part of the assessment of Objective 2. She said that the poster was done brilliantly by some but the essay was not very well done.

Changes in assessment of practical skills:

Cathy reported that she changed the way she assessed practical skills at Year 13 to fit with the requirements of the new physics curriculum, spelling out exactly what they were assessing. She stated that 'students planning an investigation as part of practical skills' did not figure much in her practical programme at the beginning of the year,

however later she incorporated it into her lessons and now her programme included assessment of planning an investigation.

Changes in content:

Cathy reported some changes in the content that was covered. She mentioned that there had been changes in Year 12 that involved removing a lot of the optics that was in their old scheme, and introducing historical developments of the theories of light and radioactivity. She said that for the Year 13, she was looking more into the effects of nuclear energy. She suggested that, while on the whole the topics were the same, there had been a change in emphasis for some topics.

Changes due to students' abilities:

Cathy suggested that she had had to make some changes due to the range of abilities of the students taking physics. She said that there had been a need to make the programme fit the students rather than going along with a more theoretical programme; she changed from emphasising deriving formulas to emphasising understanding.

Lack of change:

By midway through the first year of implementation, Cathy reported that she felt that the new physics schemes had not changed her teaching hugely from what she had been doing before although the emphasis was a bit different. She said that the students were going away with the same set of notes: "It wasn't as traumatic a change ..." In spite of the lack of major change, Cathy reported that she felt that her teaching fitted with the new curriculum in terms of satisfying the regulations and weightings for assessment.

One example of similarity of approach is found in the special topic of medical physics. Cathy thought that Medical Physics had a personalised approach dealing with the effects of physics on people's lives. However, while in past years her students did some interviews about how people would deal with cancer, that year they did away with the interviews because "it got tricky" to interview cancer patients.

By the end of the first year of implementation, Cathy expressed her opinion that her approach or teaching style was not too much different to the previous years. She said

that she had not really got into teaching from contexts though she used a lot of real life examples in her teaching. She explained that one reason for this being so in the Year 13 was that she and her colleagues were driven by exams. At the end of the year, Cathy stated:

I didn't really do anything very different to what I've done before. In terms of the new curriculum being implemented, either I didn't do what I should have done or I was already doing enough. I am not sure but I felt as though I just did more of the same.

Changes due to natural progress and growth as a teacher rather than the document:

The changes due to the new curriculum that Cathy could identify were not obvious. She suggested that her course used to be more theoretical in terms of teaching using abstract problems which did not relate so much to everyday examples. She said that while her scheme still looked that way, over time her teaching has evolved and she now teaches from the basis of everyday things far more than she used to. She reported that her teaching style involved looking first at real-life examples, then coming to the theoretical ideas and then the applications. "And in everything there is more of an awareness of bringing out the relevance to everyday examples." Cathy suggested that the effect of utilising everyday things more in her lessons was that her students were more enthusiastic, they saw the relevance of physics in their daily lives and they had a better understanding now than they used to have. They seemed to understand why certain formulas were used and not just use them by rote. "I think students have a better idea of what physics is rather just a formula ..." This change evolved over time and was seen as a natural progression of her growth as a teacher.

Changes anticipated for the future:

Cathy reported that she wanted to change her physics curriculum further: have more emphasis on the effects of physics on people's lives (as she felt that it had just been tagged on to her programme that year); give more choice for the Special Topic at Year 13 such as starting electronics as a possible choice; and pace herself better so there was time to do more individual experiments towards the end of the year for the Year 13. For the Year 12 class, she thought that she needed to review the overall course and decide what to emphasise, how deep to go and how the whole course should hang together.

Another change that Cathy reported that she wished she could make was for her lessons to become more hands-on and student-oriented, with students directing their own learning more rather than her directing from up in front. However, she could not see that happening in the near future.

Cathy noted that her way of teaching might change in the future according to whether there were external examinations in the new qualifications because then she would have to emphasise more on getting the students ready for the examinations. She said that the focus at the senior secondary level is to do well in the external examinations.

7.3.7 Summary of Cathy's views

Table 3 contains a summary of the main features of Cathy's views related to *Physics in the New Zealand Curriculum* and its implementation. As for Brian, Cathy's pre-implementation views were mainly about her current teaching scheme and the post-implementation views were about *Physics in the New Zealand Curriculum*. It can be seen that Cathy's views had not changed markedly pre- to post-implementation. Her views aligned quite closely to those of the writers.

Throughout the first year of implementation, Cathy felt that her physics teaching had not changed markedly from that prior to implementation. This was exemplified by Cathy saying that her students went away with the much the same notes as before. Table 4 illustrates that Cathy had beliefs about physics that were in accord with *Physics in the New Zealand Curriculum*. However, during the interviews, Cathy mentioned some less obvious changes that were part of her natural progression towards the directions set out in *Physics in the New Zealand Curriculum*. These included a movement away from just focusing on theory; having a teaching style that incorporated more everyday examples and applications to the physics theory; and emphasising understanding of the way formulas are used rather than just acquiring them by rote. Moreover, as seen in Table 4, Cathy indicated that she wanted to change her physics curriculum further with more 'physics and society' inputs, hands-on physics, and self-directed learning.

Views about Curriculum	Pre-Implementation Views (about her current teaching scheme)	Post-Implementation Views (about <i>Physics in the New Zealand Curriculum</i>)
<i>Philosophy</i>	Focus is on content and theories in old teaching scheme based on exam prescriptions. The basis of her physics course is formed by “basic core ideas that govern the universe”. These ideas need to be unified at the end of the course “where all the bits fit together”.	Physics taught as a useful science that affects people’s lives rather than as hard theory where one has to be good in mathematics. Purpose of physics education to produce independent learners with good understanding of concepts and being skilled investigators is seen as important.
<i>Achievement objectives</i>	Existing written school scheme is a “strange document” and did not reflect her teaching practice. Exam prescription guided her lesson planning. Understanding the concepts is seen as more important than mathematical descriptions. Aim also to encourage active participation from students.	All three objectives seen as important aspects of physics education and especially glad to see the inclusion of ‘physics and society’. However, objectives not really used to build her teaching scheme except to cross-check that new scheme complied with them.
<i>Learning contexts</i>	Learning contexts were mostly in the form of applications or real-life examples of physics concepts that were taught beforehand.	Used teaching from context for some topics. Thought that physics ideas could get lost in the contextual pedagogical approach outlined; lacked the knowledge and expertise to utilise some suggested contexts in her teaching.
<i>Assessment</i>	Followed exam prescription closely. Used a lot of discussion in class to assess use of physics language and understanding.	Followed new exam prescription closely. Changed marking of students’ experiment reports; now marked also on ‘planning an experiment’ as an investigative skill.
<i>Physics and society</i>	Already had this dimension in her classroom physics curriculum (e.g., interviews with patients undergoing radiation treatments as part of Medical Physics).	Has always incorporated ‘physics and society’ into her teaching. However, have now added extra assessment in this area. Used the contexts of medical physics and amusement park physics.
<i>Contents</i>	Learning certain core content viewed as aim of the physics course. Contents oriented to exam prescription, personal relevance, and fun (e.g., blowing bubbles for thin film interference).	Content still viewed as main aim of her physics course. Made small changes in content and its emphasis in her teaching scheme that reflected the new physics curriculum document.

Table 3: Summary of Cathy's views about the physics curriculum (pre- and post-implementation of *Physics in the New Zealand Curriculum*)

(The post-implementation column of Table 3 will be looked at again in the concluding section of this chapter and contrasted with the features of Brian's and the writers' views.)

Beliefs/Change Influences		Cathy's Views
Fundamental Beliefs	<i>Nature of physics</i>	Basic ideas in physics govern the universe and can be applied in many situations. Physics ideas are relevant in everyday life.
	<i>Learning</i>	Students build knowledge for themselves. They link physics theory taught with what they already know. Learning occurs through the construction of something relevant and personal (e.g., "girl friendly" contexts for physics lessons for girls).
	<i>Pedagogy/practice</i>	Teaching is a student-centred activity. Relevance of physics in everyday life is important in lessons. Teacher sets up environments where students can extend their knowledge through drawing on their own experiences and through discussion in class. Teachers need to present lessons in a progression of ideas so that students can form links. They need to illustrate physics theory with real life applications (but can be limited by teacher competence in technological contexts).
Change Influences	<i>Professional development</i>	Attended initial teacher development sessions on new physics curriculum. Attended one on Unit Standards and writing schemes of work. Appreciated time to share ideas with other teachers. Did not find in-service courses which involved an emphasis on computers useful.
	<i>Implementation needs</i>	Main need to have some planning and preparation time. Also need small group support from other physics teachers to share ideas. Need to have professionally prepared resources to help teach some aspects of the new curriculum such as 'physics and society'. Need to build greater expertise and confidence with technological contexts to better deal with applications. Need more time in the classroom to be able to accommodate some of the change in emphasis. Have no external exams to confine teaching, so can try innovative methods suggested in the new curriculum document.
	<i>Implementation planning</i>	Designed new physics scheme from the exam prescription, a sample scheme and the curriculum document. The curriculum document was used mainly for physics content and philosophy though cross-checked to see that the new teaching scheme related to achievement objectives.
	<i>Current change</i>	Physics teaching scheme not changed much because of new curriculum except for small changes in content. Assessment of experiment reports incorporated the marking of different investigative skills. Made use of more real-life examples.
	<i>Openness to further change</i>	Future changes anticipated towards incorporating greater emphasis on effects of physics on people's lives, more hands-on activities and students directing their own learning.

Table 4: Summary of fundamental beliefs and change influences for Cathy

Cathy's case illustrates how a curriculum change can become part of a learning cycle that commences very slowly in the first year of curriculum implementation. Cathy was consciously modifying her approach to teaching as feedback about the effects of her teaching on learners were received, professional development opportunities occurred, and she began to consider contemporary ideas about education and physics education. She was aware that lack of time, lack of knowledge of the curriculum change and lack of support from other teachers stood in the way of rapid change. However, in her own terms, she was engaged in ongoing change and the new physics curriculum was clearly part of her on-going development as a physics teacher.

7.4 Conclusion

This detailed presentation of two physics teachers implementing a new physics curriculum has delved into the processes they underwent in interpreting and reformulating the curriculum for their classrooms. It has also set out how these processes interacted with their backgrounds, their beliefs, their existing pedagogies, their personalities, and also the professional development and other supports that they had experienced. Table 5 reproduces the summaries of the two teachers' views post-implementation found in section 7.2 and section 7.3 and compares these views with the writers' views.

While both Brian and Cathy viewed the changes they had undergone in the year of implementation as being minimal, Table 5 highlights that the two teachers interacted with *Physics in the New Zealand Curriculum* in quite disparate ways. Brian was quite dismissive of the curriculum document as having no added value for him. He was contented with his practice and not enamored by the alternative ideas professed in the document. In fact he saw some of the ideas in the document as being not "real physics" and having been included for the weak physics students. Thus Brian was not open to the curriculum change.

In contrast, Cathy liked some of the ideas promoted by *Physics in the New Zealand Curriculum*, especially those that related physics to society and had made some small attempts to try some of the ideas suggested in the document. However, timetable, school responsibilities and exam constraints curtailed her attempts; leaving her with

the feeling of not having made any change. Thus Cathy demonstrated an openness to the curriculum change.

	Brian's Views	Cathy's Views	Writers' Views
Curriculum: Philosophy	Philosophy of curriculum is to relate physics to everyday contexts and experiences; this was found to be too vague and open to different interpretations by teachers.	Physics taught as a useful science that affects people's lives rather than as hard theory where one has to be good in mathematics. Purpose of physics education to produce independent learners with good understanding of concepts and being skilled investigators is seen as important.	Physics involves exploring the physical world, understanding and describing the phenomena. Learners should be enthusiastic about physics; be good communicators; skilled practical investigators; and be able to see the relevance of physics to their world.
Curriculum: Achievement Objectives	Objectives on physics concepts and investigations considered as core physics. Objective on 'physics and society' not essential. Require a different mindset to teach from these objectives. Objectives used only as a check whether teaching scheme complied with them.	All three objectives seen as important aspects of physics education and especially glad to see the inclusion of 'physics and society'. However, the objectives were not really used to build her teaching scheme except to cross-check that new scheme complied with them.	There are neo-behaviourist constraints on the aims of physics education; however, teachers need to integrate objectives when planning teaching programmes. Content and contexts are related to objectives at the different levels.
Curriculum: Learning Contexts	Did not find suggested contexts useful. Deriving physics from contexts not used because "messy", not an efficient way of teaching physics.	Used teaching from context for some topics. Thought that physics ideas could get lost in the contextual pedagogical approach outlined; lacked the knowledge and expertise to utilise some suggested contexts in her teaching.	Contextual pedagogy not necessarily the main thrust of the document. Rather, relevance of physics in everyday contexts and lives of students are more important.
Curriculum: Assessment	Concentrated on formal tests and exam assessments rather than new curriculum assessment examples. However, utilised new criteria of investigative skills when assessing practical work.	Followed new exam prescription closely. Changed marking of students' experiment reports, now marked also on 'planning an experiment' as an investigative skill.	Aware that Unit Standards form of assessment could thwart the ethos of the new curriculum. Regarded the assessment examples in document as being varied and useful for formative assessment as well as conveying the expectations of the objectives.
Curriculum: Physics and Society	No changes made for this new objective. Used medical physics module previously taught. Felt notion of 'physics and society' caters for less able physics students.	Has always incorporated 'physics and society' into her teaching. However have now added extra assessment in this area. Used the contexts of medical physics and amusement park physics.	Regarded the link between physics and society as an important aspect of the new curriculum. Equivocal about bringing in assessment of ethical issues in 'physics and society'.
Curriculum: Contents	Contents considered the main aspect of the new physics document. Teaching scheme can be generated from contents only without regard to objectives.	Content still viewed as main aim of her physics course. Made small changes in content and its emphasis in her teaching scheme that reflected the new physics curriculum document.	Pleased to have content included in curriculum document. Viewed specification of content as indicative of the progression of levels according to its difficulty.

Curriculum: Implementation	Designed school scheme based upon existing scheme, new exam prescriptions, and practical work units. Ensured that content matched new curriculum then cross-checked that the scheme related to the achievement objectives.	Designed new physics scheme from the exam prescription, a sample scheme and the curriculum document. The curriculum document was used mainly for physics content and philosophy though cross-checked to ensure that scheme related to achievement objectives.	Teachers should take responsibility for developing their own teaching schemes that address the objectives in the document and reflect the philosophy of the new curriculum. They should adapt the ideas to suit their schools and students.
Curriculum: Changes	“No, I haven’t changed.” However utilised new criteria for assessing practicals. Planned future changes unrelated to the thrusts of new curriculum – organisational changes, structured assessment, more marking, using more computerised equipment, and new reporting system.	Physics scheme not changed much because of new curriculum except for small changes in content. Made use of more real-life examples. Assessment of experiment reports incorporated the marking of different investigative skills. Future changes anticipated towards incorporating greater emphasis on effects of physics on people’s lives, and also more hands-on activities and student-directed learning.	Changes toward teaching more physics in contexts of relevance to students, more physics and society, more investigative project work and formative assessment. The emphasis is a change in the approach to teaching physics and not so much in the content.
	Brian’s Views	Cathy’s Views	Writers’ Views

Table 5: Corresponding views of *Physics in the New Zealand Curriculum*

The two case study teachers had started from different points on the continuums of belief and practice as they commenced their implementation of *Physics in the New Zealand Curriculum*. Both of these teachers ended up remaining at the same disparate points on the belief and practice continuums after the first year of implementation. Brian maintained a pedagogical approach that centred on teacher exposition and formal laboratory sessions that addressed the technical side of physics and valued summative assessment. Cathy maintained a pedagogical approach that was student-centred and related to what physics can do for humans, and valued informal assessment (although she acknowledged that what she taught was exam driven for Year 13).

The case studies of Brian and Cathy are revealing of the characteristics of the state of the curriculum change situation that they were involved in. Both teachers said that at the end of the first year of implementation they had not made any substantial changes. That was their overall feeling, but to just classify the success of the reforms contained in *Physics in the New Zealand Curriculum* in terms of changes in teacher behaviour in the first year of implementation would be misleading. The difference between the

teachers in their attitudes towards the new curriculum was profound; with Cathy having a view of *Physics in the New Zealand Curriculum* very similar to that of the writers, whereas Brian was antagonistic to most aspects of the new curriculum.

What was very similar for Brian and Cathy was the process that they were involved in from the time that the *Physics in the New Zealand Curriculum* was released. Both teachers embarked on revising their senior physics teaching schemes and did so by beginning with the new examination prescriptions. The teachers then ensured a content match for the school scheme and brought ideas from others in their community of physics educators. Finally they referred to the achievement objectives in the document to ensure that the objectives were covered. Both case study teachers did not use the achievement objectives directly to design their teaching scheme as intended by the writers of the curriculum document.

Because the over-riding concern of both these teachers in the first year of implementation was that of compliance with the new curriculum framework (even if superficial), it is difficult to analyse the issue of whether the curriculum was leading to long-term teacher change. For the first year of the curriculum implementation, it would obscure the issue of change to use labels to differentiate the two teachers: such as Brian as “resisting within accommodation” and Cathy as “adapting to existing practice” (see Chapter 2) because what was occurring was more fundamental. They were both complying with the requirements of the Ministry of Education while maintaining their unique identities within their community of practice.

Cathy had a positive view of *Physics in the New Zealand Curriculum* and some of the key ideas of the document were established in her practice. She wanted to move further in its directions. However, what stood in the way of teacher change for her, were the assessment requirements, and time itself. This is a situation that has been recorded often by researchers (e.g., Brown, Taggart, McCallum & Gipps, 1996; Shipman, 1974; Silvernail, 1996). Thus the outcome of the curriculum implementation remained in the balance at the end of the first year of implementation as the structural constraints of the schooling system, particularly the qualifications system, would influence the extent that teachers with attitudes supporting change such as Cathy, would indeed embrace change.

This chapter has laid out the complex scenario of implementation of a new physics curriculum. From the viewpoints of two physics teachers, this chapter has demonstrated that the two teachers' responses to *Physics in the New Zealand Curriculum* were highly contrasting. This leads to the question: How did a wider sample of teachers respond? The next chapter will cut across comments made by all ten teachers to give the range of responses in the areas of exploration in this research.

Chapter 8 ➤ Summary of Ten Teachers' Views

8.1 Introduction

The previous chapter (Chapter 7) dealt with two case studies of physics teachers interacting with *Physics in the New Zealand Curriculum* and described their implementation of the new curriculum. In this chapter, the stories of Brian and Cathy are placed in the context of the views of eight other physics teachers in secondary schools in and around the same New Zealand city. The views that are presented here are about their interactions with the new physics curriculum document, the professional development that they had undergone, and the implementation of the new curriculum with a focus being on changes that were brought about in their teaching due to the new curriculum.

The comments made by the ten teachers are summarised to illustrate the range of the various views. These views were elicited from the three interviews for each teacher as described in Chapter 4. There was an initial interview, before implementation of the new curriculum; an interview during the first year of implementation and an interview at the end of the first year of implementation. The ten teachers are given pseudonyms: Andy, Brian, Cathy, Danny, Eddie, Fred, Gary, Henry, Ingrid and Jack for anonymity.

It is important to bear in mind when reading the following sections that, for example, when some teachers mention a certain point, it does not mean that the others do not have such a view. It is a limitation of focused interviews that responses are not always comparable because the context and the wording of the questions are unique for every participant. Also participants are free to bring up other aspects that are not raised by the interviewer. Thus in this study the focused interview data can be regarded as only a sample of the views held by a small group of participating physics teachers.

In detailing the interpretations of teachers about their experiences of implementing the physics curriculum, I have attempted to report in a strictly qualitative way. What counts in my research are the possibilities of responding to the curriculum in particular ways, and not the count of the most frequent responses. Thus, in order to

write in a flowing qualitative manner, I have avoided using the language of the number of responses. However, in writing about more than one interviewee, one is forced to acknowledge that any object is a member of a class related to quantification. Thus, one of the distinctions between “Teachers said ...” and “A teacher said ...” is the relative magnitude of the numbers of interviewees being reported on. To be consistent in the writing that follows, conventions of meaning for the following words are adopted:

‘A’ or ‘One’ – indicates that the reporting applies to a single teacher.

‘All’ or ‘Every’ – indicates that the sentence applies to 10 teachers.

‘Some’ or ‘A few’ – indicates that the sentence applies to 2-5 teachers.

‘Most’ or ‘Many’ – indicates that sentence applies to 6-9 teachers.

‘Several’ or ‘A number of’ - is a wider category that indicates that the sentence applies to a number of teachers more than one.

Using the conventions above, I am able write about the data qualitatively without providing a sense of false precision.

8.2 *Teachers’ Views of the Document*

8.2.1 Inclusion of content in the document

The inclusion of lists of content for the different achievement levels in the document was seen as very useful by all the teachers. It gave a greater understanding of what is required to be covered. This was in contrast to the discomfort felt by teachers when faced with the draft document that did not specify any definite content. It was preferred over the Science document as well because it was more prescriptive with the listing of the contents. The lack of prescription of content would have been difficult for a beginning teacher as most teachers relied on their background experience of teaching physics to know aspects of the content to be covered. One teacher felt that the content alone was enough to generate a teaching scheme and there was no need for the achievement objectives. He saw content as the main part of physics and the achievement objectives were the “framework”. Other teachers too saw content as being the central aspect of physics. Teachers viewed the inclusion of content as a

major strength of the document as they saw the objectives set out in the document as vague. This is illustrated in the following comment from a teacher:

Again this has gone back really to our prescription base and this content is prescriptive which is a lot better than the Science document. ... I realise what the Science document's failing was; it didn't prescribe sufficiently and the only reason I felt comfortable with the document was my experience. ... If I read "describe how physical theories and models have developed", I would wonder what on earth I was going to do. It was not until I read that (list of topics) now I come down here and look at what can possibly be done and it says here conservation of momentum, centripetal force etc. ... So that was a major comment, it was a lack of prescription (in the Science document) and I felt far more comfortable with this physics document as it is now than I do with some of the others. (Henry)

The inclusion of content enabled teachers to step back into their old shoes and deal with the content as they were used to instead of the achievement objectives:

So I would say the way it is written this way is better than the Science way because it is more prescriptive in terms of it actually does lists the contents which is what we physics teachers were looking for, we didn't want to work just from the achievement objectives. (Danny)

The feeling was that teachers would focus on the content and use that as a basis for their teaching programme:

I think we teachers will probably go for that, look at the content boxes because that's where you've got something to hang onto and then OK they can be all related to this (achievement objectives), but OK do teachers need to know that? I think if they had this (the listed content), then they can generate a teaching scheme without even knowing this (achievement objectives). (Brian)

Several of the teachers felt that the content in the new curriculum was not significantly different; the main change being in the portrayal of physics:

I don't think the content is much different to what we've already had all the time. I am certainly not expecting to have to teach very different things but the change in emphasis is that physics is a useful science rather than physics is a hard theory thing ... (Cathy)

Whatever you have here is no different from what I have taught a few years back, except now I have Newton's Law of Gravitation. ... So on the whole, the content is almost the same. (Fred)

Teachers seemed to have understood that particular aspect of the intended curriculum; that the main change is in the way physics is presented rather than changes in physics content or topics which were very minor.

8.2.2 Choice of topics for the content; optional content

Most teachers felt that the basic core concepts and knowledge in the main content areas were written into the curriculum document content. It encompassed the basic fundamental ideas that were important to physicists:

The strength of the document for the teacher is that it is a good framework in terms of content as it covers the basic fundamental ideas that are important to physicists. (Jack)

The listing of compulsory content and optional content was seen as good as it encouraged teachers to go beyond the core content. One teacher said that she would choose to do optional content that was familiar and relevant. Some teachers were unhappy to see some of their pet or interesting topics deleted from the content. One teacher felt that the choice of content was not logical in certain instances, for example, the topic of momentum being left out in Level 6 Physics but not in Level 6 Science. For some teachers the reclassification of some content as optional meant that tough decisions had to be made about what to include in the classroom curriculum:

Kepler's Laws yep, (going through the list of optional content), didn't do that, ... we talked about relativity because the students were quite interested in that; so we dealt with that a little bit. Doppler red shift, we dealt with that a little bit. I felt that a lot of these things ... kids used to find them quite fascinating, were quite interested in them. So we certainly do some of the optional content, not all of it. Polarisation, I would have liked to have done but time was against us. (Andy)

You can always find something that's interesting and their explanation is out of the prescription, out of the course. (Brian)

What's the story with thin film interference because I taught it this year. Somebody has said to me that they thought that it was out but I wasn't sure so I taught it anyway. Then there is no point in me blowing bubbles for days. (laughter) Bubbles were so much fun! (Cathy)

However, several teachers expressed appreciation of the structure and flow of the curriculum document:

Yes, I think the seventh form (Year 13; Level 3) flows very nicely, one thing leads on to something else which leads on to something else, and even the teaching tools, you learn one thing and then you use that in the next topic, the whole thing builds ...(Cathy)

Teachers were on the whole happy with the inclusion of content topics for the different levels. The minor changes caused some degree of confusion as well as a sense of loss of some interesting activities associated with the removed topics. The optional content listed in the final document went some way towards diminishing that response as some teachers said that they would be teaching those optional topics. The inclusion of content resulted in a big step back into the familiar old ways of designing the teaching schemes from content topics. Consequently, it also resulted in a sense of relief and reduced confusion about what to do about the new physics curriculum.

8.2.3 Levels in the document structure

Most teachers saw the levels in the document as corresponding to the various senior years of physics at school, that is, Levels 6, 7 and 8 corresponded to Years 11, 12 and 13 respectively. The levels were seen as a rough guide to where students were at in their physics knowledge/achievement. However, as most schools did not do physics at Year 11, teachers felt the need to teach Levels 6 and 7 to their Year 12 classes. When the two levels were combined, the change of content in the new curriculum compared to the previous prescription for Year 12 in effect was very little. The content to be covered under each level and the corresponding mathematical requirement were seen as the indicator of the level of difficulty:

I seem to remember that I had some concerns about the physics going from Level 6, I felt that sometimes the progression didn't seem to be very smooth like there seem to be a little bit of, er, obviously they are trying to make it a progression, in some places there seemed like there was no real change at all, just the wording gets changed a little bit. In other places it seems like it is a bit ad hoc. I guess it is one of the problems with writing this kind of thing is trying to, in a one liner or in a single sentence, trying to define it in such a way that is distinct from a previous level and still distinct from the next level. ... With this (final) version of it though because they've moved to having topics, there is not the need. This (list of topics) specifies the depth of it. It's a guide within the topic area, if you compare the length of the mechanics section there (at Level 6), the length of the mechanics section here (at level 8), there is obviously a difference, which would have been the sensible thing to do in the first place, if they haven't been holding so fast to this idea of being non-prescriptive. (Andy)

Level 8 is seventh form, Level 7 is sixth form, and Level 6 is fifth form. ... We repeat topics in our sixth form. Our Form 6 will cover a good chunk of Level 6 and Level 7. (Brian)

As set out in the curriculum document, the topics were not repeated at the different levels. Jack saw this as limiting because he thought that physics should be taught in a spiral way with the same topics being revisited at different depths each year:

I still would teach topics that are not in Level 7, can't assume prior knowledge because it's not there because it is not taught in fifth form Science. If it is taught at fifth form Science, they may have had about two weeks at it. Therefore we need to reinforce it. So it's assumed knowledge that is reinforced. To me you can't help but teach some topics again, one year after another, but you are enhancing what you have done to start with and you are building on it. It's a spiral process to my mind. ... In terms of teaching, we certainly repeat; not just spiralling, but snowballing; you have the nucleus which gets bigger and bigger by having more around it. (Jack).

Some teachers felt that the interconnectedness of physics knowledge was not always well served by the levels structure. Fred pointed out that there was an interconnectness when it came to angular and linear momentum but they were listed separately at different levels. He thought that it would be inevitable that topics would be revisited and that should have been written into the curriculum document:

When it comes to angular momentum and conservation, if you wanted to talk about angular momentum, you will have to talk about linear momentum, ... People can't say just straight away that this is our syllabus and no physics teacher is going to buy that because you cannot possibly even if you have done it in Form 6, you'll have to reinforce it and when you talk about that then you might as well put in there so that we know for sure and that gives the flexibility for the examiners or anybody to frame the questions such that they can then rationalise between the linear and the rotational momentum. (Fred)

In summary, the anchoring of the different levels to a list of content topics was welcomed by the teachers. It gave them a sense of what to cover and how deep to cover it in their teaching. However a quirk generated by the writing brief of not repeating topics already in an earlier level went against most of the ideas about teaching held by the physics teachers interviewed. They mentioned having to repeat topics from previous levels to build on and further the concepts in the field. The breaking up of the topics into Levels 6 and 7 was seen as superfluous as most schools do not have a Year 11 Physics class, choosing instead to have the more integrated subject of Science which covers Biology, Chemistry, Physics and Earth Science. As

the coverage for physics is quite sparse in Year 11 Science, most teachers were teaching topics from both Levels 6 and 7 to their Year 12 classes. Thus these teachers were not averse to modifying the stipulations in the curriculum document to suit the students they teach.

An interesting comment from Fred, “no physics teacher is going to buy that”, indicates that physics teachers are led by the values or norms of their subject discipline and there can be resistance against stipulations that violate those views. The phrase gives a sense of there being shared values within the community of practice of physics teachers.

8.2.4 Main thrusts of the document – contextual teaching and relevance to everyday life

There was a strong feeling among the teachers that the general thrust of the document was promoting the contextual teaching approach and the relevance of physics in everyday life. They used words such as “pushed”, “promoted”, “encouraged”, “thrust”, “gave permission” to use the contextual method. Following this approach involved the relating of physics concepts and ideas to the real world, seeing the relevance and impact of physics. The sample contexts given in the document seemed to confirm it for them.

The teachers had reservations about contextual teaching saying that it was not a method conducive to teaching physics, as physics ideas get lost in the many other aspects which come to the fore, and the teaching does not lead anywhere. The contexts suggested such as “kitchen technology” were seen by some teachers as being too wide making it difficult for them to know where to start their teaching. Some teachers were not happy to incorporate contextual teaching saying that it was not real physics:

My focus will be content to context, whereas I get the impression this is context to content. I don’t think it is a dichotomy. I mean it is not as if you have to separate the two but if you’re going to emphasise anything, I will emphasise the content idea to develop a context. Whereas I sort of had the impression from people I’ve talked to and the course I’ve been on, they’d like us to say “Well here’s an appliance or here is an example or here’s an idea that embodies physics ideas. Let’s find out what they are.” I say it is too inefficient

for my way of thinking, too slow, too cumbersome, and I will lose too many students too quickly doing it that way. (Gary)

Thus they felt that students would lose interest as the contextual method was cumbersome and slow. The inefficiency of this method to generate quick learning is highlighted in the following comment:

I have a sneaking suspicion that the agenda is towards context as the way to teach and if that's the agenda then I have a minimal problem with that. I would find that a bit more challenging than I want to be at the moment and also I have a feeling that it wouldn't be as efficient as what I do. And I do think I have a responsibility to my students to give them a certain level of content. I mean I could spend all year on one context and maybe not cover the content that I feel I should have. (Gary)

On a more positive note, Henry felt that, in principle, teachers should teach contextually but they are not prepared for it:

I don't think contextual teaching is the answer to solve all our problems but it is important that we teach contextually but we have not written contextual units of work in physics. It is just as it is in this document. (Henry)

Contextual teaching lends itself to the new direction in the physics curriculum of emphasising the societal aspects of physics. Some teachers could see how the new thrust enabled physics to be seen as useful and not just hard theory and mathematics. They thought it could be seen as a more people-based discipline; part of everyday life, with historical ideas, and reflect the impact of physics on society:

I think that pure physics is such a narrow focus that if we don't bring in the applied ideas or explanations for some of the technology around us that we are not doing our students any service, especially for those not carrying on in pure physics. ... and for those that are going on into pure physics, again it opens them up to, especially with the present technology, ideas about society and impact. It opens them up to ideas that they might not have actually thought about ... that doesn't hurt them to find out about these things. (Ingrid)

The pros and cons of using the contextual method as seen by physics teachers were discussed in this section. The general feeling by most of the teachers was that it was too inefficient a method to teach physics in senior classes.

8.2.5 Interpretations of objectives

The achievement objective statements were mostly found to be rather general, unrealistic, very wide and insufficient to work from. One teacher, however, felt that they were useful to analyse one's teaching. Among the three objectives, Objectives 1 and 3 were found to be quite similar to the previous physics curriculum. Objective 2 which dealt with the nature of physics and its impact on society was not new according to some teachers, but the new curriculum had given it more emphasis. One teacher felt that Objective 2 was something new to him with an environmental impact type of emphasis. Some teachers felt it encompassed a historical approach, of which the extent of coverage was unclear. Most teachers liked the inclusion of that objective but would not be treating it with equal importance as the other two objectives which dealt with concepts and experiments respectively:

I think in certain ways we are already doing that (Objective 2) also. I mean, for example, like the radioactivity topic, the effects of radiation on society; whether it is industrial, or agricultural or medical, the effects are there also. ... but the thing is the focus is not there; we don't look at it as a necessity sometimes. If you have time, you can bring it in, but it is a good thing because it is still related to their lives. (Eddie)

Some criticisms leveled at Objective 2 were, for one teacher, that it was not real physics but more appropriate for social sciences and the less able physics students. Another teacher felt uncomfortable teaching Objective 2b which could deal with ethical issues because he felt that he should not be correcting students' ideas and values when it came to ethical issues.

There was a fair bit of controversy in the interpretation of Objective 3b which involved practical investigations of appliances to identify the applications of physical concepts and principles. There was a sense of confusion and that persisted even towards the end of the first year of implementation with comments such as "it is still a bit tricky", "it is difficult to understand" and "it does not fit in". The interpretations of Objective 3b ranged from 'explain concepts to arrive at relationships' to 'fiddling with instruments and gadgets but not doing any experiments or practical investigations', to 'pulling things apart or building things up from scratch'. The confusion with Objective 3b resulted in some teachers not doing anything about it at all:

Investigating a real application is complicated (Objective 3b); most real applications aren't single purpose applications ... to focus on one particular aspect of application, gets clouded over by all the other complications that are involved. ... Many of the real things are too technically advanced or dangerous, so we have to contrive a very simplistic situation. Then the bright kids switch off. (Andy)

Some teachers described using achievement objectives retrospectively to analyse their new teaching schemes in terms of how the objectives would be covered. These teachers described using content as a main basis for developing their teaching schemes:

The value of breakdown of the objectives in the current model is in helping to analyse my own teaching. ... I have devised my courses more on the content rather than the achievement objectives. (Jack)

I think because of the way we do things, the achievement objectives will come out, I mean we will deal with understanding concepts, principles and models, we will definitely be applying concepts and models. We will have to think carefully about how to develop 7.2a (Level 7, Objective 2a). ... I still think 7.2b is a bit tricky. We will probably do the same as with 7.2a, we will put a bit of effort into getting at least one thing through the year ... Well we do 7.3a a lot so no problems there. And 7.3b will be if we get to it, we get to it. Basically the difficulty is understanding what's implied by the statement. (Gary)

One teacher questioned the value of objectives that were not tested in the examinations. Despite the note on page 15 of *Physics in the New Zealand Curriculum* stating that the objectives should not be interpreted as requiring equal amounts of time (specifically that Objective 2 is to account for less course time than either of the other two objectives), some teachers were still under the assumption that all objectives were equally weighted.

Thus the focus on the objectives was diminished by the inclusion of specific content in the final curriculum document. The teachers' attitudes toward the different objectives were coloured by their personalities, backgrounds and beliefs about what was physics. There was a fair bit of confusion about the meanings behind the wordings of the objectives. This is further discussed in the following section.

8.2.6 Clarity of document

The new curriculum was seen by the teachers to have a wide range of ideas and a lot of material in it but there was not enough depth and detail to plan their teaching programmes. The inclusion of content helped to clarify the situation to a certain extent as the objectives were seen as vague. However even that was not sufficiently indicative of the depth of coverage and there was some confusion about the specifics of what to include under the content topics. This was especially a hurdle to planning practicals and demonstrations. New areas such as atomic and nuclear physics at Year 11 were also prone to confusion about depth of coverage. For several teachers, the wordings of the objectives were found to be unclear about the extent and depth to which they had to teach, and they felt that the document was open to different interpretations by different teachers when they were trying to implement it in their classrooms. The following comments from Fred, Eddie, and Ingrid exemplify this.

Fred felt that there was a need for a common understanding of the document nationally by all physics teachers:

I have nothing against the document but how are we going to implement it. How will it be? It must be really something that nationally all physics teachers will understand, 'right this will be the content that we have to complete, these are the concepts that must be exposed to the students and they should be conversant with that here'. Here every physics teacher could interpret it in a different manner. (Fred)

Eddie liked the ideas on contextual teaching in the document and predicted that over time, physics teaching would move in that direction. However he indicated that he needed more clear instructions on what exactly it was advocating:

There are certain things that I like and certain things that I don't. What I like is the concept behind it is that we have more ideas on how to bring out the way to teach contextually; so that would in a way influence our way of teaching and gradually, it takes time, our teaching will become more in a way more related in that way. But it means, because everything in this document is a bit not very specific, a lot of things need to be really spelt out more accurately and specifically. (Eddie)

Ingrid felt the lack of specification of depth for each topic a major stumbling block as she was quite isolated as a sole physics teacher at her school:

From a teaching viewpoint, I think the major criticism is that it is not detailed enough as to the depth that's necessary at each level, that leaves a lot up to individual teachers and especially teachers that work alone such as myself, there is sometimes a little bit of doubt that I am sort of doing the right thing. (Ingrid)

Some teachers had developed the view that every objective needed to be tested and that was something they could not do. This was especially the case for Objective 3b which some teachers found difficult to understand as to what was being implied by it. This confusion is voiced clearly by the following comment from Andy:

... something that I like clarified is “do you need to test every objective?”. You need to have presented it or covered it but do you necessarily have to test it? (Andy)

As mentioned in the previous section, some teachers found the suggested contexts in the document too vast and it was unclear where to start. One teacher would have liked to know which contexts were compulsory for the exams. He suggested that teachers needed more training to develop appropriate assessments in dealing with contexts:

We still have a way to go and if there is any area in this document that staff still need a lot of training in, it is developing assessment tasks that in fact are valid. (Henry)

Clarity was certainly an issue with most of the teachers as they tried to make sense of the document, sometimes in isolation and sometimes at in-service courses. Even at the in-service courses, those running these courses have not had any contact with the writers of the document themselves.

8.2.7 Flexibility afforded in the document

Most teachers saw the document as a non-prescriptive, open document. They could work out their own prescription based on it which could include the teachers' characteristics, expertise and interests. They felt that there was enough flexibility afforded by the document to fit programmes to the students they had and be quite comfortable with it:

I suppose the way it is being presented is to allow the teacher also to be quite free to be able to do whatever the teacher feels is appropriate in the contexts and also of the nature of the students the teacher is having. So it is in a way

more freedom for the teacher to develop to use the techniques of teaching.
(Eddie)

They did not feel that they had to follow the physics curriculum document exactly. One teacher mentioned that he was comfortable with it and chose to ignore what he found too difficult. Some teachers felt that the document told the teachers what to cover but not how to teach it. They saw this as enabling teachers to choose their own methods of teaching and focusing on what was important to them:

But again it comes down to somebody having to make some decisions as to how you actually teach or the depth of teaching. That seems to be the style these days, everybody makes their own decisions (laugh). That's the New Zealand way, everybody does their own thing basically. (Danny)

Yes, but in terms of this, I mean it is not a prescriptive curriculum so I mean you've got the opportunity to tailor it to the way you want to teach and things you think are important. There's enough freedom in there for me to be happy.
(Cathy)

Though the lack of prescription had frustrated several teachers, it also gave the teachers flexibility to infuse their own methods and decisions on how deep to go into each topic in their teaching programme. This was appreciated by a number of teachers as it allowed them flexibility in the design of their own classroom curriculum.

8.2.8 Purposes of Physics Education section in the document

Some teachers commented on the initial part of the document where the purpose of physics education was explicated. They found that some of the points mentioned were very general and could be applicable to any subject. They all concurred with the point that students needed to become 'good communicators'. The other points applying to students that the teachers highlighted as significant were 'independent thinkers', 'show understanding', and have 'scientific integrity'. As one teacher put it, that section was excellent, and useful to get things in perspective, to provide an overall picture and direction for their teaching:

I think it (Purpose of Physics Education section in the document) is good, I think it is excellent. I think we should throw the rest of this away and focus on that. ... I think you know for me you could throw all the rest of this away except perhaps the examples that they give, because they are quite useful in terms of looking if you're delving around for new ways for your practical examples of doing things, but I mean if you just had this (Purpose of Physics

Education) as a very concise guide, operational guide in front of you all the time, I think it gets things into perspective. (Andy)

However, most of the other the teachers said that they did not focus on the front pages of the document that laid out this perspective. Some teachers commented on the 'Approaches to Teaching and Learning in Physics' section which sets out suggestions for the pedagogy; one teacher strongly agreeing with it while the others had not incorporated the suggestions into their programmes.

The writers were careful to set up the platform for physics education in New Zealand secondary schools, especially in the first few pages of the document. In fact the points on the purpose of physics education (see Appendix A5) were adopted in 1993 as policy by the New Zealand Institute of Physics. However, many teachers did not focus on these front pages and went directly to the pages on the different levels and what to teach. This undermined the thrust of the whole document because its philosophy was incorporated in those front pages.

8.2.9 Identification of investigative skills

Another area that many teachers felt was being promoted was investigations and this was especially highlighted with the identification of the different investigative skills in the document. They liked the delineation of these investigative skills which made them change the way they assessed and reported their practicals (experiments). Danny said that identifying specific skills made the assessment of practicals more manageable:

Yes I've tried to identify the achievement objectives that we're trying to assess in each assessment task, and also certainly in the investigative skills. I think the curriculum has been useful in terms of identifying the specifics skills that we are actually looking at and therefore trying to assess, and so splitting our first practical sessions into more manageable investigative skills, we identify two in any particular practical assessment task. That's been very useful. Previously you know the idea of you do some experiment and then go and write your report, take two weeks and then mark your report, it was all a bit wishy washy and not too sure how to mark it or what we were assessing them on. I think we are clear on that one now. (Danny)

Henry thought that new dimensions in reporting student skills in the reports sent out to parents had come about as a consequence of attempting to implement the skills section of the curriculum document:

That approach is good and we're getting more data on the students and we're looking at how they work as a team. We're looking at perseverance; we've even looked at safety. We report on that. So our report format was not good, it needs changing. But we were now able to quantify their abilities in problem solving, even if it was saying they are inconsistent in their approach to problems. We could at least say that. Some had a particular consistency of approach and are particularly good at applying their physics information, linking physics ideas, reapplying them to new situations. We could not have reported about that before. That is a direct result of trying to implement the skills section of this document. (Henry)

Every teacher in this study incorporated the investigative skills section in some way or another. The identification of the investigative skills in the document was new to physics teaching and it was supported by the examination prescription that applied exact weightage for the different skills. Many teachers were not happy with the existing ways of marking experiments. Thus it seems that 'investigative skills' being something different from existing practice, being something that answered a need for change (a dissatisfaction), and being supported by the assessment structure was a particular thrust of the document that was embraced by all the teachers. Only one teacher had some resistance to this but eventually she too incorporated it into her methods. It was something 'do-able', well defined and examined (i.e., a component of the high stakes assessment). Interestingly, the writers did not feel that this section had much input from them as it was taken mainly from the science curriculum document. So what the writers had considered as of little importance to them in the document turned out to be the one change that every teacher in this study made due to the new physics curriculum document. Thus, in Wenger's terms, the response from the teachers to the document could not be predicted and the document was focused on in unintended ways.

8.2.10 General comments on the document

The document was apparently not read very thoroughly by most of the teachers. It was seen as a blueprint that needed to be followed but it was not used much to develop their schemes of work. The exam prescription statement that followed later was used by some teachers more than the curriculum document to plan their work.

Some teachers had positive comments about aspects of the document. They mentioned good features including the many ideas, examples and possibilities for the teachers to use, the inclusion of content, and even the summary flap at the end of the document. Other teachers were lukewarm or saw little value in the new curriculum document. As shown in the comments from the two teachers below, the attitudes toward the document ranged from being quite positive in terms of seeing it as a ‘mind shift’ to seeing it as being quite redundant for teachers:

It is a big development in the past twenty years for physics and science education. The document is good in saying “let’s do experimental investigations”. ... the change to more descriptive way was important because with maths you can blink yourself and just narrow it too much. In the physics document, the curriculum is fundamentally not changed; content is still there ... The mind shift is then how do you take that content and make it more meaningful for the kids. (Jack)

It’s token putting it onto what’s asked to do. But I just teach physics. To heck with this (curriculum document). I don’t know who dreamt these up. It sits on the shelf. I pull it out occasionally. It’s not inspiring. I don’t really think about it.” (Brian)

8.2.11 Summary

The document in its written form represented a cultural artifact in the field of physics education. It embodied the aspirations of what physics education should be at secondary schools. However the response to this artifact by teachers showed that they utilised it in different ways bringing to it the attitudes and experiences that they had developed over the years. Some of the responses were collectively shared as the teachers belonged to a community of practice, but there were some responses that were unique to individual teachers as they brought to their interpretations other aspects of their personality and attributes. In particular, the document was seen as supportive for writing up the content of their teaching schemes as the spread of content topics was seen as covering the basic physics concepts well. However, there was some degree of confusion with respect to the depth of coverage and the pedagogy to be used to implement the new physics curriculum.

8.3 Professional Development

8.3.1 Formal professional development

In the years leading up to the official year of implementation of the new physics curriculum in 1998, there were a number of in-service days. In 1996, at the time of the initial interviews for this research, most of the teachers had experienced two days of in-service professional development organised by the science advisory service for secondary schools in the region. The focus for the first day was on the new curriculum document. It looked at the difference between the old and new curricula with respect to the content, and then the objectives, and also how to fit the course content under the different objectives. The focus for the second day was to change teachers' attitudes from more traditional methods to more student-centred methods with more practical and contextual approaches. These ideas were linked to the Unit Standards.

However the courses were run at the time of the moratorium on the new school curriculum reforms by the Teachers' Union and some teachers found them not very useful because there was the fear of overstepping the bounds of the moratorium. Most teachers attended the courses but one teacher went for the equivalent Chemistry courses instead and another teacher had enough funding for only one teacher from his school to attend and so he was not able to attend any professional development that year.

In 1997, the focus for professional development was shifted to Unit Standards assessment. This was a very new method of assessment being promoted by NZQA and a two-day course, of which one day was funded by NZQA and the other by the school, was run. This course trained the teachers in the Unit Standards form of assessment and also in the writing of teaching schemes incorporating the Unit Standards assessments within the new curriculum. Most teachers expressed that they appreciated the chance to air their difficulties and learn how to manage dual assessment (i.e., trialling Unit Standards while continuing with the usual examinations as well). However, not many were convinced to take on Unit Standards immediately. The course was run by the National Unit Standards Coordinator from Christchurch. He brought along a sample teaching scheme designed by a group of teachers in the South Island incorporating Unit Standards into a teaching scheme based on the new

physics curriculum, and gave out copies to teachers attending the course. Several of the teachers mentioned that they found that sample scheme very helpful and that they felt confident in using it as it was based on the new curriculum and worked on by a number of people.

Another course was run at the end of that year by two physics teachers showing how to incorporate more practicals and investigations into the physics teaching programmes. There were also demonstrations with equipment that were not normally found in schools and they were set up at the University of Waikato.

In 1998, the official year of implementation of the new physics curriculum, there was an in-service course in the last term of the year. It was run by one of the writers of the curriculum document. (I was present at this in-service day.) The teachers' focus was on the details of content of the new curriculum, in particular, the prescription for Bursary examinations. By this time, the importance of the Unit Standards had been downplayed and its future as the main senior school subject assessment method was uncertain. Surprisingly many of the teachers were still unsure of the changes in the content of the prescription for Year 13 in the last term of the first year of implementation with the Year 13 Bursary examinations just a few months away. Most of the teachers who attended the course found it very useful.

In most of the professional development days, teachers were exposed to new ideas provided by those who ran the course. There was also a sharing of ideas among the teachers themselves. All teachers found it a good thing to be able to talk to other physics teachers, and share their common difficulties and ideas:

I thought that it was very valuable and it certainly highlighted what were the priorities and [laugh] concerns of the teachers and it wasn't the curriculum, it was what was in the prescription and out of the prescription was the biggest concern. Understandably so I mean we have a duty to our clients. ... And the other thing I mean it's terrible really but sometimes you feel as though you are floundering around but it is a kind of reassurance in knowing that other people are having the same problems. I mean some of the questions that were coming up, clearly a lot of those people had got to the end of year and they still weren't aware of what was in or out of the prescription. (Andy)

Some physics teachers who felt rather isolated, as they might have been the only physics teacher in their school or they were too busy to communicate with their

colleagues at school except on a very rushed basis, found the physics in-service days very useful:

I think you need lots of these things (in-service days) because it's probably a time when teachers can get together and discuss these things because we are all in the same boat in a way grappling with new emphases and when you are busy you don't always have time to think on your own. Time out with other physics teachers is good, very valuable. (Brian)

Not all the ten physics teachers were able to attend all the available physics in-service days in those three years for various reasons. Insufficient funding was mentioned especially when there was more than one physics teacher in the school:

No I didn't go on them, couldn't afford to send, I sent one physics teacher from my school but I didn't go myself. To fill you on that picture, when that course was running, this school had no money left for professional development at that stage. And within my department I had to do a bit of a juggling act with using the amount of money that was given to us in a number of areas, senior sciences, biology, chemistry, all the junior science areas. (Andy)

Furthermore some teachers felt that there was insufficient professional development on the new physics curriculum; the emphasis was on the new science curriculum and Unit Standards:

The professional development in the last few years was a good opportunity but that had gone into training for Unit Standards unfortunately. It was a waste of time. (Ingrid)

This situation could have been the result of the evaluation from the teachers on the in-service day in 1996 when they requested that they would like to know more about Unit Standards. At that time they thought that the Unit Standards form of assessment was inevitable.

Some teachers mentioned that they would like professional development sessions that helped to enhance their competence in certain areas such as some of the new electronics gadgetry and assessment.

None of the teachers interviewed were strongly involved in the development of the physics curriculum document with the majority of them not writing submissions to the draft document. Some did put in submissions either as a science department or as part

of the Science Teachers Association or as individuals. However they felt that the document was fait accompli and they were powerless to effect any changes:

Teachers felt that it was fait accompli, really, it was too late to change, why are they bothering? But we'd put a submission in. (Henry)

Some teachers felt that it was not their role to have any input into the curriculum development but merely to implement it:

I don't want to design the curriculum. I've got more to do than that. Someone else can design it for me and I'll teach it. I am a good teacher; a basic classroom teacher and I've got enough to do to keep my classroom running without designing curriculum. If I've got a good textbook, a good programme, someone's told me the parameters that they want me to teach to, I'll do that. (Gary)

One teacher felt that teachers as writers would have constrained the document because of their narrow focus:

You can't have too many. If you try and take into account everyone's opinion to start with you actually won't achieve anything. I think it is better to take a few who have got opinions and are willing to put them down. Then you let everyone else bitch and moan about it. (Henry)

However, in contrast to the above views, one young teacher felt that as she had now gained in teaching experience, she would like to be involved in future curriculum development:

I was a beginning teacher when the curriculum was developed and so had no confidence to put ideas in. But now I am keen to be involved in curriculum development and do a curriculum development project. (Ingrid)

8.3.2 Informal professional development

All the teachers came to grips with the document initially by reading it on their own. They made sense of it coming at it from different background experiences. The forms of informal professional development experience mentioned by the teachers included discussions during their school's science or physics teachers' meetings, having some teachers to call on when having difficulties, a helpful Head of Department, and perhaps more importantly, their involvement in the various educational projects mentioned below. The actual delayed timing of the initial curriculum implementation

due to the moratorium on the curriculum reforms meant that the informal phase was of some duration:

Within our school we have, we've spent a little bit of time looking at it, especially when it first came out, we spent a bit of time looking at it but we were keeping one eye on the dates when it had to be implemented and thinking that it is a way off yet, we don't have to do anything about it at this stage, and if they'd stuck to the original dates these holidays would have been the time we would have spent getting something organised. (Andy)

Among the teachers interviewed, some experienced physics teachers had time out of the classroom as science advisers, some were involved in research projects, some were doing courses at the university, some were involved in running sessions at in-service days, some were involved as facilitators, examiners or prescription writers for the Science examination or curriculum, and one was a Unit Standards moderator.

To me, as interviewer, the two teachers who had time out and experience as science advisers seemed most well-versed in understanding the curriculum. They had taken the opportunity in their time out to make sense of the document and also to plan activities to help other teachers to understand and implement it:

I had a year out as science adviser, physics adviser two years ago, or 1994, so I looked at it in more detail during that year although in fact during that year because the science curriculum was being introduced, I was actually spending most of my time working with the science curriculum rather than the physics one. So I'm familiar with the layout of all these documents in terms of aims, achievement objectives, learning experiences and so on. ... I think the most important aspect is actually having the year off in the advisory service. I learned a damned sight more than I would have learnt in coming to grips with the curriculum and then having to help other people to implement it was tremendous for me, very useful. ... (Came to grips with the document) mainly by myself, but then I was in the advisory service, a lot of people there are ... working on it ... being a prescription committee writer ... I was in contact with more people through that exercise, and visiting schools ... So I got help from a number of areas and it was easier to do that because I wasn't teaching. (Danny)

8.3.3 Summary

The professional development most teachers had were the annual in-service days as well as special training programmes set up to familiarise teachers with the science curriculum and the unit standards assessment. Formalised training to deal with the *Physics in the New Zealand Curriculum* document was not available but it was dealt

with in the usual in-service days. These in-service days were run by fellow teachers though the Units Standards training was run by the unit standards physics coordinator from Christchurch. A moratorium placed on the new school curriculum by the PPTA (Teachers' Union) delayed the implementation date by a year and that eased the pressure on teachers. The physics teachers' in-service day towards the end of the first year of mandatory implementation was found to be useful for the teachers as one of the writers of the physics curriculum finally got to share his views and guide the teachers for the first time, four years after the publication of the physics curriculum document. Thus the teachers on the whole had to make sense of the document and the intended curriculum, and write their teaching schemes without much guidance or support from the writers of the curriculum document.

8.4 Teacher Change in Practices and Beliefs

The changes, or no change, made by the ten teachers in their practices and beliefs due to the new physics curriculum have been collated in the following section under different sub-headings and this is followed by a brief summary of what each of the ten teachers felt about whether they had made any changes to their physics teaching. The main purpose of this section is to give the breadth and depth of the different responses by the teachers so as to illuminate this situation of curriculum change. The analysis is intended to be strictly qualitative and will not quantify teacher responses. (To do so would be statistically invalid given the small sample size.)

Most of the teachers did not feel the need to change as they already had good working programmes based on tried and tested ways of teaching physics over their years of experience. However they did dabble in some changes as they felt that that was what was required by the new curriculum document. The following sections deal with the changes that the teachers said that they had made.

8.4.1 Designing a new physics scheme

One of the areas where teachers had to make a change was in writing their new physics schemes. These were guided by forms sent out by the NZQA that had to be completed by each school listing down their teaching and assessment schedules. Most teachers already had existing teaching schemes which to some of them were well

written and stored away, or stored in their heads, seldom referred to, and which may have differed vastly from what they were actually doing in their classrooms. This curriculum change situation gave them an opportunity to revise their teaching schemes in the light of what they were doing and the new curriculum document. However the dilemma was whether to revamp the whole programme or merely to incorporate changes into their existing schemes:

At this stage I'm not too clear whether I would just modify or just identify achievement objectives with their exceptions and sort of slot in investigative skills and so on as part of the way they are laid out now or completely rewrite it. (Danny)

There was a range of methods by which the teachers fulfilled this requirement. One teacher had already revised his scheme for the ERO (Education Review Office) in 1993 and based the changes that he had made on the recently published draft physics curriculum document at that time. Several teachers relied heavily on a sample scheme that was devised by a group of South Island teachers which they were given at an in-service course. Some teachers referred to the sample scheme after they had written their own schemes. The availability of a sample teaching scheme based on the new curriculum designed by a group of South Island physics teachers encouraged some teachers not to radically change their existing teaching schemes as the sample scheme did not appear to be too different from what they already had:

What I found was when I compared my scheme with what's in here (sample scheme), it actually lined up almost exactly the same so I haven't had to make much change at all. (Andy)

Most teachers mentioned that they referred to the physics curriculum document, the exam prescriptions and their existing schemes when designing their new programmes. Several teachers stuck to the exam prescription for the Bursary exams (Level 8) very closely but the prescription for Year 12 (Level 7) was not very informative as it referred teachers back to the curriculum document. For most of the teachers, their new teaching schemes retained much of what was in their existing schemes with some alterations to it especially in the area of content topics that were changed from the old prescription. Four of the ten teachers changed to another school during the period of implementation and some of these teachers had to accommodate and adapt the teaching schemes existing in their new schools:

I didn't want to reinvent the wheel. It's still physics at fifth form (Year 11) level. The existing scheme was sensible, logical, at the right level, well laid out with good facilities – certainly I didn't want to change. ... So the change to this year is not that dramatic. Obviously there were changes, certain levels of the content which had been taken out, and a new area involved, nuclear physics which is reactors and things. (Danny)

The assessment schedules were re-written to incorporate the assessment guidelines given for identifying the different investigative skills and their weightage in the internal assessment component of the examinations. This was especially adhered to for Year 13. The sample scheme by the South Island teachers incorporated Unit Standards at relevant points in the schedule and some teachers wanted to try using this mode of assessment as well as the usual assessments (i.e., dual assessment).

8.4.2 Modifying the content addressed

The examination prescriptions with emphasis on content topics for the new curriculum, were felt to be not very different from the previous ones. The changes in content were fairly minor and most of the teachers said that they would continue to teach the topics that were dropped or shifted to optional content if they thought that the topics were interesting for the students. The content in the physics curriculum was still seen as central despite the introduction of contexts and so teachers foresaw they would be doing the same topics as in the previous years. The focus on content led to a lack of scrutiny of the other aspects in the document such as achievement objectives and sample learning contexts. Apart from queries about one or two little topics, the level of content listed in the document was acceptable to the teachers:

Well in the sense that I have decided to match our course to the content of this, there's complete correlation, no problems, even the suggested optional content, looks like we can fit it in and fit with our philosophy that we use at the moment. The main thing I see is that we really haven't dealt with the sample learning context part... (Gary)

8.4.3 Widening pedagogical repertoire

The starting point of the teacher in terms of their teaching pedagogy at the beginning of the new curriculum implementation, determined the amount of change they needed to undergo to be teaching in line with the suggestions in the new curriculum document. A number of teachers felt that they were already teaching in line with the

document in using an experimental approach and relating physics to the real world situations:

That's my traditional way. I'm a hands-on person. ...So it's just my way of doing it and that fits in well with what's suggested in the document. So I don't need to change my teaching approach. (Brian)

Most teachers thought that they had made only minor changes to their existing programmes (one used the word "cosmetic"). Several teachers had introduced a few new activities into their programme so as to incorporate some of the ideas in the new physics curriculum document.

One teacher said that he went from teaching physics as applied mathematics with an exam orientation to being more practical orientated, emphasising the different investigative skills and bringing in modern developments to show the use of physics:

I started changing my programme as soon as I read the draft syllabus. The content didn't change at all but the way I would teach them did. ... Formerly I concentrated more on knowledge, derivations; but now I look at it differently, like with practicals, focusing, planning ... Formerly my teaching was almost like teaching applied mathematics compared to what it is now. (Fred)

Some teachers dabbled in using some contexts, using student discussions in their teaching, and adding some variety to their assessment methods:

For contextual teaching, I'll go according to topic or lesson. I would not completely do away with contextual; I wouldn't do away with traditional approach. Whenever I feel fitting I bring in the approach that I like. ... I like both ways. ... I think because of the awareness of this document I think more and more teachers are also asking them (students) to give a short talk ... asking them to prepare a paper to give a talk, so this is just another approach ... that's another way of evaluation, so it's quite different now. (Eddie)

Most of the teachers felt that on the whole they had made no change in their teaching approach, with their physics programme and lessons very similar to those they had before the implementation of the new curriculum:

There is no difference in the seventh form (Year 13) physics programme; just basically no change in my style. When you've been doing something a long time, you get a tried and true way and you know what the kids can cope with. (Brian)

I feel as though I haven't had to really change what I have done at all in order to meet what the curriculum says. (Andy)

8.4.4 Responding to the dictates of examination prescriptions

The physics exam prescription for Year 13 was quite similar to the previous one, however, the prescription for Year 12 indicated that teachers should refer to the curriculum document Level 7; Year 13 was an external examination year whereas Year 12 was solely assessed internally in 1998. Thus teachers were more open to experimenting with some changes in Year 12. The examination format for Year 13 had changed in the few years previous to the new curriculum document and teachers had already made some change towards using contexts. Given that there was not much change in the new examination prescriptions at the time of implementation, for most of the teachers interviewed the change in the curriculum did not appear to bring about much further change:

To me, we are restricted to the exam prescription, and the exam prescriptions do not mirror necessarily with the curriculum. ... Knowing full well that teachers are going to teach to the exam prescription rather than to the curriculum because the writing doesn't tell you where to go; teachers are using the exam as to where to go. (Jack)

Several teachers spoke about attempting to incorporate new ideas, in particular, investigation skill development and impact on society, into their Year 12 course but not for their Year 13 course as that was an external examination year for their students:

The method of teaching, again Year 13, to be honest, I haven't changed much; Year 12, I think I am paying a bit more than lip service to the new curriculum but I am not yet there as regards all the investigations and the emphasis on skills development and the impact on society and so on. ... There is conflict in Year 13 because I do deliver an exam course; that's what my students want. (Ingrid)

8.4.5 Broadening the notion of investigative skills

The expansion of experiments into investigations with the ensuing assessment of investigative skills in the new physics document was focused on by most of the physics teachers. Here was a change that made marking of experiments easier and more rigorous. Furthermore the investigative skills had been delineated in the

examination prescription as well and the weightage of marks for each skill specified. This change was clear, comprehensive and practicable for all the teachers. They could still use their existing experiments but the experiment reports were marked differently using the new criteria. The teachers found the new mode of assessing practical skills useful and it gave a better spread of marks that were fairer to the students. For some teachers, their style of reporting on the students changed because of this aspect of the new curriculum:

We are trying to investigate specific skills of focusing and planning, carrying out the investigation, reporting, processing information. We are actually trying to get the data on the kids to write their reports on it. ... I feel we've introduced more practical work. ... our approach in class I think has changed for the better because we have run experimental design, we've given them problems to solve, we've given them a design brief, and they had to go away and set up how they think they are going to investigate a practical. ... something that has never happened in the history of physics in this school. (Henry)

8.4.6 Implementing other assessment changes

Several teachers made some attempt to incorporate assessment of the 'new' Objective 2b dealing with physics and society. Some teachers trialled the new assessment scheme, Unit Standards. A broader range of assessment ideas were encouraged by the document and although some teachers made no changes in their assessment methods, it did influence the way they taught:

I think the two major changes would be trying to link, well I have been trying to put how ... the physics we are doing in the classroom, does affect, well can explain a lot of the things they do in normal lives, in their everyday lives. Bringing in the society/physics interface and also getting them to assess, I suppose, or get the students to work in groups much more, ... and present their findings in groups rather than just working totally individually. That would be the two major differences. (Jack)

For one teacher, the changes he made were due to the Science document rather than the Physics document. This was because he had realised its value and now he had a major focus on skills. His assessment strategies had changed with more variations than before. His assessment had also become focused on application and understanding, whereas previously knowledge tests were solely based on recall.

8.4.7 Changing teachers' attitudes and thinking

Some teachers talked about a shift in their attitude towards student-centred methods. Students were encouraged to do more research and work cooperatively. Data was gathered on skills such as teamwork, perseverance and safety. There was a shift in the philosophy of learning physics where it was deemed more useful to gain skills rather than just a body of factual knowledge. There was more willingness to have class discussions and not consider it a waste of time. Topics were introduced through contexts, demonstrations or practicals rather than just starting with a formula:

Communications skills, yes we comment on communications through reporting etc., information skills ... and problem-solving skills where we think we've got the practical skills inherent within it.... We had looked at appliances because we try to relate the practicals to circumstances that kids will experience in their everyday lives. (Henry)

One teacher felt that the biggest shift that he felt in recent years was due to the new science curriculum. As for the new physics curriculum, though the content of the new syllabus was basically the same, the major change he reported was his mind shift on how to make the content more meaningful for the students:

Everything to me is really based on teachers concerned having been introduced to the science document as opposed to the physics one as such. ... the draft of the science was such a huge change and then the actual science document was again a big change; it was a totally different thing. ...In the physics document the curriculum is fundamentally not changed; the content is still there ...The mind set is then, how do you take that content and make it more meaningful for the kids. (Jack)

One teacher became committed to facilitating students to think for themselves (become independent thinkers) and would set up situations for that. He used the contexts suggested in the curriculum document, demonstrated relevance of physics in everyday life and got his students to be more inquiring:

The curriculum is pushing the contextual method. I think you choose one context and apply the concepts to the context – training students to think in that manner. I couldn't possibly have every contextual situation; but train them how to think, how to approach, how to reason out. (Fred)

One teacher changed his earlier belief that a quiet classroom is good. He moved to believing that a quiet classroom with lack of interactions among students is not the best way to learn:

Too often teachers like having a quiet room. – students working by themselves without interacting with others. Now I am recognising that's not the way for the kids to learn best. (Jack)

Another teacher was unsure whether to attribute his changes in attitude to his development as a teacher or to the influences of the new curriculum document. He suggested that he moved to more student-centred methods when he became more confident as a physics teacher:

I don't know whether it is a result of the document or whether it's just me developing as a teacher; I really don't know but it happened about the same time. (Gary)

8.4.8 Accommodating philosophical and societal aspects

Achievement Objective 2, which related physics to its role in society incorporating historical, philosophical and ethical aspects, was dealt with in different ways by the teachers. Some teachers felt that the usual Special Topic that they did for Year 13 took care of incorporating that objective into their programme. As for Year 12, they incorporated more emphasis in connecting the topics with their relevance to society. Students worked on posters and other research assignments to satisfy Objective 2:

There were some changes in the requirements for assessment ... requirement to show that we're looking at the impact on people's lives ... the historical development of science aspects of physics ... So this year we've got a poster assessment or essay which we never had before which will actually highlight those two areas. (Cathy)

8.4.9 Implementing contextual teaching and augmenting real-world relevance

The teachers felt that the document was promoting contextual teaching. Many of them felt that contextual teaching was not a suitable pedagogy for senior school physics. One comment was that using contexts was difficult and teachers needed to be very well organised:

If I only had two or three physics classes and lots of time to spare in classes of ten or fifteen, yes, (that is a better way of teaching). But in the real world with one hour classes, you can't. ... It is very time consuming and I can't do more than say one or two topics a year. ... you've got to be incredibly well organised and focused in approaching it that way. (Danny)

The type of methods used, whether contextual or more traditional, was also affected by the topics that they were teaching. Since the Bursary (Year 13 external) examinations had become more contextual in recent years, teachers brought in contexts of real world examples more into their teaching as students needed to be able to apply physics principles in new contextual situations:

The curriculum is pushing the contextual method. I think you choose one context and apply the concepts to the context; training students to think in that manner. I couldn't possibly have every contextual situation. But train them how to think, how to approach, how to reason out. ... The Bursary questions are more contextual now and students should be able to apply the principles to new situations. (Fred)

One teacher said that he reacted badly to the inclusion of contexts in the document. After hearing from other teachers at in-service courses that it need not be taken as an extreme method of teaching, he became more relaxed about it. He still saw content as central to his physics teaching and worried that context would be done at the expense of content. He had changed in his attitude towards contextual teaching from being dead-set against it after feeling there was a compulsion from the document to teach contextually, to being more willing to dabble with some simple contexts. He described his efforts as only "cosmetic moves in that direction" (Gary).

Some teachers did not feel confident to use contextual methods but they felt that the document gave them permission to do lots more contexts. Some teachers observed that the shift from more theoretical and abstract teaching towards having more relevance using everyday real-life examples had a good effect on students who were responding more enthusiastically and having better understanding:

When we try to include lots of activities that students are involved in in real life such as kicking balls, it takes a lot of time, rather than a controlled experiment set up in the classroom ... Kids seem to be enthusiastic, far more enthusiastic about doing things, familiar things, than about more traditional experiments. (Cathy).

8.4.10 Planning changes for the future

At the end of the first year of implementation of the new curriculum, teachers were feeling more relaxed about *Physics in the New Zealand Curriculum*. They talked about incorporating more ideas from the document into their lessons for the following year. There were a number of plans to improve on the experiments and practicals, especially in expanding the incorporation of the investigative skills, providing more hands-on experiences and having more open-ended investigations:

I would like to have more open-ended experiments or practical investigations where the students sort out how they are going to investigate the task that they are given; or go even one step further and let them decide what task they are going to choose. (Andy)

I would still like to see more open-ended investigations for students. I think it is more useful to gain, not just the body of knowledge, but I think it is more useful to gain the skills that go with it. (Henry)

The use of computer equipment in physics teaching was another area that some physics teachers wanted to incorporate into their programmes:

I would really like to incorporate computers into my physics teaching a lot more. (Andy)

We have got some data logger equipment and I'd really like to bring that in in some area; but the problem with that is the time factor. (Brian)

... we have got this Pasco, these computer programmes, so we are trying to introduce more experiments on that. ... And also maybe a bit of electronics, I am not so sure. ... The idea is there now, we are starting Form 4 electronics; just to expose them to the basic components and maybe later on we will see how it goes. (Eddie)

Several teachers expressed a desire to incorporate into their programmes more of Objective 2 that related to the effects of physics on people's lives:

And describe influences of everyday physics-based applications on their lives, I guess we are paying lip-service to it, certainly we're not putting much emphasis on that at all. ... I would like to move a little towards it. For instance my approach to the atomic and nuclear topic is certainly based on people's lives. (Danny)

Some teachers talked of plans to review the senior physics programmes to better fit the new curriculum, to plan a few changes to accommodate the curriculum statements and changes in assessment:

I think I need to look at the whole philosophy of how deep we go and what bits we do and what bits are important and how it all hangs together. It's kind of looking at the overall course. (Cathy)

Yes, I am going to plan some more changes. I am still not sure what. I am so snowed under with other things right now that I haven't had the time. That would be one of my holiday things to do; to look at what we have done, look at the new prescription and say how would I want the two to marry better than they have? But again it is a constant situation of subtle changes rather than you know large ones. (Jack)

One teacher was keen to do all the content in the document, including the optional content, and wanted to get a more efficient programme running. He was worried how to compress the content areas so as to fit them all into one year:

I have actually started to plan for next year and I have gone through and made sure that we've got materials that are suitable for all those content areas and I have looked at the optional content and decided that we can probably fit most of that as well, even if it is only in a very cursory way. ... I can see that we'll be in a couple of years pretty sussed on this (the document) ... We really want to set in place ourselves for a year doing all that content and getting a more efficient way of making sure we've covered it all. (Gary)

Most teachers were waiting to see the new school national qualifications to decide on any further changes in their teaching programmes:

At the moment we just see how it goes, now that we have a new thing (new qualifications) coming here, so we have to look at it. At the moment we just stick to what we have, what we had developed and then if there are any changes that need to be made then we will go accordingly. (Eddie)

For the foreseeable future, it would be interesting to see how the new qualification set up will affect Year 13. At the moment I don't plan large changes. (Ingrid)

One teacher felt that his curriculum was similar to that of the new physics document in spirit but different in terms of the emphasis. For the emphasis to become aligned in the future, he said that there was a need for more money and time to be spent on changing his programme:

I think the spirit of the document is we want the kids doing physics, doing it well, enjoying it, achieving success, and moving on to the next level. ... But I feel that the vehicle they want to use doesn't suit me, particularly at the moment. So unless a lot more money, a lot more time is spent to set up a lot better situation, I am achieving those objectives without too much change to what I am doing. (Gary)

8.4.11 Summary of each teacher with respect to change

The teachers in the sample took up various ideas from *Physics in the New Zealand Curriculum* to incorporate into their physics lessons. The summary of how each teacher viewed the extent of change in their practice due to the new physics curriculum at the end of the first year of implementation is shown in Table 6 below. With respect to the breadth of change, section 8.4 indicated a wide range of changes mentioned by different teachers. These included changes in content, pedagogy, investigations, inclusion of 'physics and society' and focus upon physics contexts. Some teachers also mentioned changes in attitude towards being more oriented towards student-centred methods. These changes tied in with the intentions expressed by some teachers of moving towards a more open-ended investigative approach to teaching physics.

While some teachers said that they have made some of the changes mentioned in the sections above, most teachers indicated that the depth of change in their physics teaching was not so profound. This was because the content was much the same, the textbooks used were the same, and the way they taught the topics were the same. In effect, for most of the teachers, they felt that there was no pedagogically significant change in their classrooms.

For some teachers of Year 12 physics classes, there was a willingness to try the ideas of the new curriculum in these classes as there was no restriction by external examinations. However, Year 13 classes were taught with the critical end of year examinations in mind. At Year 13, most teachers thought that there was no room to try the more innovative ideas of the new curriculum. Once again school and assessment structures can be seen to act against the effective implementation of the new curriculum (see also Madaus, 1991; Smith & Rottenburg, 1991).

Teacher	Change	Comments
Andy	No change	<i>"I don't see that there is any major change. I think this is implying that there should be some major changes in most areas that you have asked about before, but the reality is that I mean that's not going to happen until I find ways of freeing up more time in class to explore them."</i>
Brian	No change	<i>"My course here is basically much the same. Although you know I refine it every year and change it for the following year."</i>
Cathy	No change (Year 13); Some change (Year 12).	<i>"I didn't really do anything very different to what I've done before. So you know, I think in terms of the new curriculum being implemented, either I didn't do what I should have done or I was already doing enough; I'm not sure but I felt as though you know I just did more of the same."</i>
Danny	No change	<i>"I didn't feel that I could extend into any other areas of the curriculum. I was more concerned that I was actually covering the content that would be examined. ... I'm afraid this course this year I have gone back to the traditional boring introduction: scalars, vectors, motion, mechanics and so on."</i>
Eddie	No change	<i>"I think there is not much difference, not really much. Because I follow the prescription and there are certain parts of the prescription that's in and some parts are out, that's the only difference though; and I am only aware of it ... only during the recent course. So otherwise basically they are the same."</i>
Fred	Changed	<i>"I have really gone through that syllabus, that curriculum and derived my own prescription of it, the one that I gave to you. Because I said to you before that I liked the document and so I think I have done a good job of it."</i>
Gary	No change	<i>"From my point of view, not much change. ... My thing, anyway as a person, always make changes slowly, no need to get excited, to make big changes. ... I prefer to make cosmetic changes until I have to do something else."</i>
Henry	Changed	<i>"But our approach in class I think has changed for the better because we have run experimental design, we've given them problems to solve, we've given them a design brief, and they've had to go away and set up how they think they are going to investigate a practical. ... Obviously the curriculum document is a real major influence to me and gives me a lot of good ideas and gives me direction."</i>
Ingrid	No change (Year 13); Some change (Year 12).	<i>"For Year 13, I don't feel that I have changed my teaching style or the content apart from the small changes that have been made to the exam prescription. Year 12, I have been aware of the change of intent and I have attempted to modify perhaps one or two topics ... the rest I have treated much the same."</i>
Jack	Some change	<i>"At seventh form or Year 13 level, I wasn't involved with it in my new school here so I did not do anything. With Year 12, I adapted the programme that X has set up and adapted my programme that I had run at Y (previous school). So I adapted the two of them into the course, which was not fundamentally different to what I had done in the past. The one aspect that I have done which I haven't done in the past was to bring in the interrelationship between physics and society."</i>

Table 6: Summary of teacher's views of their changes after the first year of implementation of the new physics curriculum

An interesting dichotomy arose with respect to the changes promulgated in *Physics in the New Zealand Curriculum*. All the teachers took up the inclusion of investigative skills whereas the inclusion of contextual teaching was resisted by most of the teachers. One possible locus for the difference between teachers' response to the two aspects of the curriculum is the clarity of the proposed changes. The 'investigative skills' were clearly defined, teachers had explored them for the science curriculum document, and they were clearly identified with actual weighting for each skill in the examination prescription. On the other hand the contextual approach to teaching physics was not clearly defined: teachers were confused on when to use a context like "The Physics of Toys" to teach various physics concepts versus when to use contextual examples to illustrate concepts. Adopting a contextual pedagogy in physics was seen as very time consuming and needing a lot of teacher preparation time. Thus incorporating contextual teaching into teaching programmes was not seen as 'do-able' or practicable as incorporating the investigative skills.

There were two teachers, Fred and Henry, who said that they had changed. They both viewed their changes as being due to implementing *Physics in the New Zealand Curriculum*. Fred had been teaching physics as applied mathematics (the way that he was taught), but he was not content with that. As Head of Department, he needed to update his physics teaching scheme for a review of his school by the Education Review Office (ERO) and this was occurring at the same time as the publication of the draft *Physics in the New Zealand Curriculum*. He adopted the ideas in the draft physics document as he said that he liked them and he changed his teaching scheme then. Thus in Fred's case there was the need for change; there was an incentive for change; and there was support for the change in the form of the ideas in the draft physics curriculum document which he liked.

Henry had taken time out from teaching to work as a science adviser, and so he had the opportunity to make sense of curriculum documents as such as the *New Zealand Curriculum Framework*, *Science in the New Zealand Curriculum*, and *Physics in the New Zealand Curriculum*. As he had to help other teachers make sense of the curriculum documents, he became greatly immersed in the ideas of the new documents. When he returned to schools he tried the new methods and so he described himself as having changed. However, he felt that traditional methods of assessment in his school disadvantaged his students because the learning activities

that were based on the new ideas in the curriculum were not taken into account in his school's common assessments. He questioned the value of trying the suggestions in the document when assessment does not reflect the new physics curriculum.

In Henry's case he had time to deal with the new curriculum and he grew in his knowledge about it during his time as science adviser. However, he found that the assessment structures of his school were not supportive of his implementation of ideas in the new physics curriculum. In spite of this disadvantage, Henry's belief in the need for change, and the opportunity for reflective professional development that he had as a science adviser, ensured his commitment to the changes heralded in *Physics in the New Zealand Curriculum*.

In summary, the general feeling of most of the teachers interviewed was that they had not made any major immediate changes in their classrooms due to the introduction of the new physics curriculum. The factors that contributed towards that outcome are delved into in more detail in the following chapter.

8.5 Conclusion

This chapter has surveyed the breadth and depth of the changes in the classroom curriculum with the advent of *Physics in the New Zealand Curriculum*. It gave instances of a number of different ways that teachers had interacted with what was set out in the curriculum document. Across the teachers there was a breadth of changes, but among all the teachers interviewed, only two considered that they had made any major changes in practice as part of a profound attempt to move towards the directions of *Physics in the New Zealand Curriculum* as they saw it.

Utilising the theoretical framework of Wenger (1998), it would seem that teachers in the community of practice were interacting with the reification of envisaged practice that was set out in *Physics in the New Zealand Curriculum*. Where it was easy to move from reification to practice, the nature of the participation about the reification led to change occurring (e.g., in assessment of experiments). For those changes where the reification was obscure, then the participative movement from reification to practice was such that change tended to be held back from occurring, or occurred in unexpected ways (e.g., utilisation of existing projects in medical physics to cover the

‘physics and society’ strand). Each teacher was a participant within the physics teachers’ community of practice, but with different personal attitudes, beliefs and knowledge; different school characteristics; and different pupil backgrounds.

Many teachers could identify ways in which they had made small changes to incorporate what they felt the new curriculum was intending. The sense that teachers may have acquired attitudes that were receptive to *Physics in the New Zealand Curriculum* change is reflected in the many ideas that teachers shared about what changes that they would like to make in the future. A number of the teachers could foresee a trend towards a better implementation of the intentions of the new curriculum in the future. As one teacher remarked, “change is gradual, it takes time.” This is an important insight and will be expanded upon in the model of mandated curriculum change developed in Chapter 10.

This chapter has given the breadth and depth of views about the new physics curriculum discussed by the teachers. What is clear is that for most of the ten teachers, the way that they taught physics in their classrooms had not significantly changed with the implementation of *Physics in the New Zealand Curriculum*. This is the focus of the research of this thesis as well as the issues that stand in the way of successful implementation of a new curriculum. The following chapter will expose the emergent issues that pertain to the lack of pedagogical change based on the interview data of teachers as well as that of the writers, and discuss the implications for a more effective process of teacher change.

Chapter 9 ➤ Emergent issues and discussion on teacher change

9.1 Introduction

Chapters 5, 6, 7 and 8 laid out the writers' and teachers' views about the new physics curriculum. Although comments from the writers of the physics curriculum document implied that they were encouraging a change from traditional pedagogy, many of the teachers interviewed did not change the pedagogy they used in their classrooms. This was despite all schools having to write new teaching schemes based on the new curriculum.

This chapter focuses on issues surrounding pedagogical changes that were encouraged by the writers. Twenty-one issues related to pedagogical change were identified from the interviews with the writers and the teachers. These emergent issues are classified in this chapter under the seven change factor categories that were derived from existing literature in section 2.8. The change factors were 'need for change', 'beliefs about educational issues and the change', 'clarity of the change', 'practicality of the change in the school and the community', 'supports during the change', 'personal costs to the teacher and the possible benefits', and 'personal disposition toward change'. The emergent issues that impeded pedagogical change for the teachers in this study are set out under the change factor headings in section 9.2. A discussion on teacher change follows in section 9.3 where three key elements for establishing effective teacher change are identified.

Despite the focus on the lack of much change by the teachers, it is important to note that there were aspects of the curriculum change that were welcomed by some teachers. For example, the previous chapter has considered the two teachers who said that they had changed significantly and analysed the conditions enabling their change. This will be further explored later in this chapter.

9.2 Emergent issues corresponding to change factors

9.2.1 Need for change

Change was rejected because of teacher contentment with existing practice

Some teachers were contented with what they were already doing and did not see a need for change. They had good working schemes and felt successful with their teaching:

Stuck with my own one because I've got my own sequence of lessons and approaches for teaching each of these things, and also I have a sequence of demonstrations, equipment, and experiments that I get students to do. ... from a curriculum point of view, I felt that I was giving it a fair coverage, so there wasn't a need to make major dramatic changes at all. (Andy)

Teachers believed they were doing it already

For some teachers interviewed, the new curriculum was viewed as being not very different from what the teachers were already doing. There was an accepted rule of thumb among physics teachers that a certain percentage of the curriculum requirement could be varied and so it was possible to keep their present practice intact with little or no change:

What is actually taught in schools is still pretty much the same because what tends to happen is that whenever a new curriculum comes out, people do just what I have done. Look at it and say, "Oh yeah, what I'm doing now fits with this, this and this" and so I am covering that by doing that and so nothing changes. (Cathy)

Prescribed content distracted teachers from pedagogical issues

When the lists of content for the various levels were prescribed in the final curriculum document, some of the physics teachers were quite relieved as they had expressed unease with the draft curriculum that focused on the Achievement Objectives and not the content topics to be covered. As most of the compulsory content appeared unchanged, this caused the physics teachers to focus once more on physics topics to be taught rather than widening the scope of physics (as was conveyed in the Achievement Objectives). The old "prescription" mentality, that is, teaching to the prescription, re-emerged and the need to change pedagogy was de-emphasised:

If we are looking at the content as there, I think we teachers will probably go for that, look at the content boxes because that's where you have got something to hang onto and then they can be all related to this (Achievement Objectives). But do teachers need to know that? I think if they had this (listed content), then they can generate a teaching scheme without even knowing this (Achievement Objectives). (Brian)

9.2.2 Beliefs about educational issues and the change

Suggested pedagogical ideas were seen as unsuitable

Some ideas suggested in the document were seen by the traditional teachers as not suitable for senior physics. The inclusion of Achievement Objective 2 of the nature of physics and societal issues was seen as a diversion from 'real' physics, and contextual methods were seen as inappropriate being time consuming and inefficient in terms of producing quick understanding of concepts:

What I am unhappy about is thrusting this stuff (Objective 2) into the classroom where it reduces the amount of time that you spend on the nuts and bolts. (Andy)

If they can learn as much without the teacher centred approach, then it is good but I haven't got any proof that they learn more. (Eddie)

Teachers' pedagogical content views on the nature of physics were at variance with suggestions in document

School physics was seen by some of the teachers as having a core body of knowledge that needed to be understood by the students before they can delve into contexts and investigations. The underlying physics ideas were seen as more important than the contexts. The societal issues and the tentative nature of physics were seen by some teachers as not being important or even appropriate at the senior school physics level:

Physics is a tremendous range of concepts which explains how the universe broadly works. There happen to be a lot of very simple relationships and rules and phenomena that act in a consistent way. ... all we are doing really is learning a simple model for what's happening at a level which they and I can understand, and that the models are more complex than this and are being modified as more and more knowledge is gained. Students find that very uncomfortable. ... So I find you have got to be careful in bringing out those sort of ideas too early. ... They are young and they need to feel that what we've got here is facts and that it's absolute. ... We confuse people with ifs and buts. (Danny)

Students' perceived needs worked against pedagogical change

Some teachers felt that their first obligation was to their students and their needs. In senior physics, examinations and qualifications are important, so these teachers were only willing to change if it helped students' performance in examinations. In this respect, covering the content was seen to be of prime importance. Other needs and expectations of the students were also taken into consideration. There was a sense of viewing their students as clients and thus service to their clients involved meeting the students' needs:

I see my students as my clients, then I cater to my clientele. The teaching depends on the students. You've got to be versatile ... the content will be covered. (Fred)

9.2.3 Clarity of the change

Guidelines appeared to lack clarity

The writers despaired at the lack of a follow up document that was meant to have been written as a guideline to the original document. In the interviews, they explained that they were writing only a curriculum framework for physics, and the teachers had to develop a working curriculum from that. Wide and intensive discussions among the writers during the production of the document were pared down to one-liners in the final document that were hardly self-explanatory:

One of the main things about this curriculum is that it is a curriculum framework, ..., it is not a detailed curriculum. It is a broad-brush painting of what physics should be like in schools and that was the major misapprehension that people had. They expected much more detail ... almost like in a textbook. So what we are doing was laying out the perspective of physics in New Zealand schools. (Writer 1)

I have nothing against the document but how are we going to implement it? How will it be? It must be something that nationally all physics teachers will understand ... Here every physics teacher could interpret it in a different manner. (Fred)

Curriculum document was confusingly eclectic

a) The writers wanted to introduce teaching methods based upon constructivist ideas of learning but did not identify constructivism as the source of their ideas. Contexts were suggested implying contextual teaching approaches. Content was listed, some as

compulsory and other content as optional, and this returned the focus of the curriculum to content. Historical and philosophical ideas were incorporated as well as the inclusion of societal and environmental issues. So there was a range of principles underlying the document and teachers had to work out teaching schemes that took into consideration this eclectic array of ideas:

We also felt the document allowed people to teach in a variety of ways. Some people with thematic approach and some people are solid traditionalists, you know, who just go through the content areas, and so we thought that that gave them flexibility. (Writer 2)

b) There were different educational agendas by the different stakeholders that resulted in the document being eclectic as well (see Bell, Jones & Carr, 1995, for a thorough discussion on this). The document had to comply with the parameters of *The New Zealand Curriculum Framework* (Ministry of Education, 1993a) and *Science in the New Zealand Curriculum*, and therefore the writers had to fit their ideas within a given framework which included progression levels, achievement objectives, sample learning contexts, possible learning experiences and assessment examples. Unresolved tensions within the document were identified such as having different goals for science education: 'Science for all' ideas as well as 'Science for future scientists'; constructivist ideas as well as neo-behaviourist ideas such as achievement standards and levels of progression (Neyland, 1995); and the separation of knowledge and skills with a suggestion for teachers to try and integrate the two.

We were always told by the Ministry that the major stakeholder is the kids ... but we were also thinking of the existing physics teachers ... People felt much more happy with the curriculum when we specified content. ... Tertiary physicists wanted a good strong statement on Maths. They also wanted where the big picture was seen. Our listing out that content in a fairly traditional way I think has mollified them a bit that way ...(inclusion of ideas on) technical support came in as a direct answer to some submissions (from laboratory technicians association). The Ministry realised that there needed to be a statement on safety. The advisory group ... introduced without our knowing right at the end about the development of essential skills. ... In the form of a reference group, ... there were actually about eight who were physics teachers in secondary schools, then we had professional physicists, a couple were from universities, we had one woman professional engineer and one person from polytech.... The advisory group had teachers, university people, but yes, the New Zealand Institute of Physics put in a submission on this too, on the draft. (Writer 1).

9.2.4 Practicality of change in the school and in the community

External exams and new assessment initiatives were seen to retard pedagogical initiatives

The presence of external exams at the end of Year 13 was seen as a major hurdle for some of the teachers wanting to attempt any change in their programme or pedagogy. A teacher might attempt some change in their Year 12 physics class (which was mainly internally assessed) but make no changes in their Year 13 class, where lessons were geared towards the national examinations:

For Year 13, I don't feel that I have changed my teaching style or the content apart from the small changes that have been made to the exam prescription. Year 12, I have been aware of the change of intent and I have attempted to modify perhaps one or two topics. ... There's conflict in Year 13 because I do deliver an exam course; that's what my students want. So I feel that I follow the exam prescription more than the curriculum. (Ingrid)

New assessment initiatives in terms of Unit Standards (New Zealand Qualifications Authority, 1992b) were brought in at the same time as the curriculum changes. However, the assessment changes were seen to oppose the pedagogical direction of the new curriculum:

We have this broad curriculum now, which NZQA now has taken over with their Unit Standards, spelling them out, and in some cases I feel wrongly adapting what we were trying to do in that curriculum. ... I still don't think that the Unit Standards are able to assess the 'nature of physics' aspect to the curriculum that we put in it. (Writer 1)

Too many changes occurred at the same time

Changes in the curriculum were occurring in all subjects at all levels, and most of the physics teachers were also teaching other subjects such as Science, Chemistry, Electronics, or Mathematics. Furthermore, assessment changes in terms of Unit Standards were being introduced at the same time (New Zealand Qualifications Authority, 1992). Thus, teachers had to cope with understanding and interpreting more than one curriculum document as well as writing up new teaching schemes for each subject, and for some, the additional load of trialling Unit Standards. This was pointed out by Henry as follows:

Another dilemma, I suppose of the teachers was I think that they have got to cope with new curriculum documents, not just in Science, but Physics,

Chemistry, Biology and some of them teach to one or two or even three of those. Then they have prescriptions being sorted out and on top of that the Unit Standards. (Henry)

Other demands of teaching did not leave enough time

a) Time, or the lack of it, to focus on the new curriculum was a recurrent theme for most of the teachers. At the interviews where teachers were reflecting about their first year of implementation of the new curriculum, some teachers were still admitting that they had not looked at the curriculum document thoroughly because of lack of time:

I think the major need is time out to have a jolly good think about it (new curriculum) without all the constraints from day to day teaching. ... you need uninterrupted time to think about it. (Brian)

The writers pointed out that time to read and think was crucial to understanding the document:

So when a teacher looks at this (curriculum document), and this is where it comes to the implementation, that's going to take a lot of reading, a lot of thinking. ... so teachers can't expect this curriculum to be immediately understandable. (Writer 1)

b) Lack of time was also seen as a constraint for not using some of the more innovative approaches in the new curriculum:

I was intending to teach by the contextual approach that came from the SMER Centre, but when it came round, I couldn't because of time constraints. In fact it was easier ... to fall back on the more traditional approach. (Danny)

9.2.5 Supports during the change

Professional development was not well coordinated

Unlike the situation with the Unit Standards which was a new assessment initiative, professional development for teachers implementing the new physics curriculum was not well supported or coordinated:

Professional development was totally inadequate. For the major changes blueprinted, there should have been a much greater amount of professional development. If Lockwood (the then Minister of Education) really wanted to succeed, he should have provided the resources and training. What angered me was so many teachers working so damned hard to make it work in their own time and off their own backs without adequate support, materials and teachers

guides, and the sheer time. ... I think it has been grossly inadequate; it's been 'change on the cheap' basically. (Andy)

Unfortunately in the last few years, I feel some of the good professional development have gone into things like unit standards training ... A lot of emphasis has been put into unit standards and I can't help but feel that it might have been a bit of a waste of time. (Ingrid)

There was a lack of communication between curriculum writers and implementers

When professional development was conducted by science advisers and some teachers, they had to make sense of the document on their own as there was no direct contact or guidance from the writers of the curriculum. To some extent, this resulted in the interactions between the teacher developers (such as the science advisers) and classroom teachers being a case of 'blind leading the blind':

See we weren't allowed Teachers' Guide material in it (document). We got away with a little bit in it but that was always told us that that would be another document, supporting document. ... That never eventuated. ... I don't think that it's quite adequately had enough explanation to it. (Writer 1).

The only times that I have read it (curriculum document) have been by myself ... the in-service days that physics has had over the last two years, I have actually co-run them ... looking at how we can bring more investigation into our teaching which is part of that whole process (new curriculum). (Jack)

There was a delay due to a moratorium

A moratorium placed on the entire process of curriculum reform by the Post Primary Teachers Association (PPTA) in 1996 due to wage negotiations meant that for some physics teachers there was a lack of urgency to implement the new physics curriculum and they delayed studying the document. The in-service courses in 1996 were careful not to breach the moratorium and so the professional development on the new curriculum lacked immediacy:

There were a couple of training days but they were affected by the moratorium on the Framework and so there wasn't a lot that was helpful. ... although it was interesting discussing with the people, we were careful not to cut across anything that might be sensitive to the ban at that stage. (Gary)

I had reasonably had it scheduled to be up and ready to go completely with this (new curriculum) next year, but of course with this (moratorium) delay, it

is not compulsory so I haven't been feeling pressured into doing too much about it. (Andy)

There was no trialling of the new physics curriculum

A serious setback for the successful implementation of the physics curriculum document seen by both writers and teachers was due to the lack of trialling of it before mandatory implementation throughout all secondary schools.

Why put this (curriculum document) out without trialling it. This (the draft document) went out for comment, but how can you comment on something that you haven't used; so it's an absolute waste of time. So this (final document) has come out; this should now be trialled in schools just like Unit Standards were trialled. Get trial schools; they write their programmes on this; after a year, it is then evaluated and modified, and it will need modifying. (Writer 2)

A sample teaching scheme upheld the status quo

A sample scheme of work for senior physics designed by a group of South Island teachers was presented to these physics teachers at an in-service course on Unit Standards. Some of the teachers that were interviewed saw it as a confirmation that they were already fulfilling the new curriculum with their current practice. This was because the sample scheme was not much different from the standard practices at that time:

I felt that I didn't really have to write anything (new physics scheme) because I felt that the scheme I had already was enough, using this (the SI teachers' sample scheme) basically as my gauge because lots of heads got together and prepared this, and my assumption is that they'd have done a much better job of this than I would have done of my own, and if my own one matches up with this pretty well then I think that I'm near enough. ... I was so relieved to see this (sample scheme). This was the sort of thing we should have been getting at the start of the changes; not now, several years after the event. (Andy)

Structures and expectations in the schools did not support the innovations

Even when the teacher was willing or passionate enough to put in the extra effort to give the innovations a go, the lack of support from the other staff and school, and the need to cover the common grounds with the other classes had been a deterrent to continuing with the innovative practices. This was especially so when the teacher felt that their students were penalised because of it and were not given credit for being involved in the learning provided by the innovative methods:

The difficulties were that no matter how I approached it in class I was still faced with the same assignments and the same tests as all the others. And so there was no recognition for my students for the way I was trying to approach compared with what the others were doing extremely traditional. I still set up stations of experiments. I found that I had to spend more time and effort setting up those extra little experiments that carried no weight at all. (Henry)

9.2.6 Personal costs to the teacher and the possible benefits

Some teachers fell back on to familiar aspects

The writers wanted to encourage change but had a sense that they could not be too radical otherwise teachers may turn away. However, the familiarity of the content given in the final document encouraged teachers to remain with their existing practice:

I think we were generally wanting to be adventurous in this physics curriculum but still have our feet very firmly on the ground. We had a feeling for what teachers could take and for what they couldn't take. That you couldn't do something so earth-shatteringly different that people just wouldn't adopt it. So we wanted somehow to bridge both worlds. (Writer 1)

Some teachers were unwilling to move out of their zones of expertise

Most of the physics teachers interviewed had been teaching for a long time and they had developed programmes that were second nature to them. Following the new directions in the curriculum document would involve them in exploring a pedagogical change that would take them outside of their comfort zones. This would be risky and stressful especially since they could become more prone to criticism. Adopting new approaches would also mean that confident expert teachers could find themselves being reduced to novices in the new ways:

(My colleague) E., who is a very talented physics teacher, ... feels very very uncertain in this area because he doesn't feel confident. He doesn't feel his knowledge and understanding of physics being an experienced teacher, including me up to a point, could actually delve into some of these. We don't have the knowledge, and it is not the physics principles, it is the technology side of it often, a different ball game. ... I would not pull that stereo apart and do experiments with it; I wouldn't have a clue ... I actually think that it is an area that maybe a lot of physics teachers will feel uncomfortable with. (Henry)

9.2.7 Personal disposition toward change

Amount of change required was too much for some teachers

The starting point for change was different for the different teachers as some held ideas about teaching congruent to certain ideas of the new curriculum document but others were still very traditional. Thus the degree of shift in pedagogy required for the different teachers to satisfy the new curriculum was different. The shift seemed too big or too difficult for some teachers to manage, whereas for others the new ideas were nearly aligned with their existing philosophies. Furthermore, the required change may not be acceptable to some teachers.

Mine (teaching approach) is still quite teacher-centred and is still very traditional in the way that I just expose them to the basic ideas and allow them to do practicals related to that concept. There is less of investigative type because sometimes I feel that it is no use re-inventing the wheel. (Eddie)

Change occurs gradually

Psychologically, change processes take time. One teacher emphasised that change is a gradual process for him. The teachers were interviewed only until the end of their first official year of implementation of the new physics curriculum. Some teachers indicated that further changes in line with implementation of the new curriculum were likely to happen in subsequent years:

I am going to plan some more changes, I am still not sure what. I am so snowed under with other things right now ... that would be one of my holiday things to do ... again it is a constant situation of subtle changes rather than, you know, large ones. (Jack)

9.2.8 Summary of emergent issues

A summary of emergent issues derived from the interviews in the present study corresponding with change factors derived from the literature reviewed is listed in Table 7 below.

Change Factors	Emergent Issues
1. Need for change	• Change was rejected because of teacher contentment with existing practice. • Teachers believed they were doing it already. • Prescribed content distracted teachers from pedagogical issues.
2. Beliefs about educational issues and the change	• Suggested pedagogical ideas were seen as unsuitable. • Teachers' pedagogical content views on the nature of physics were at variance with the suggestions in the document. • Students' perceived needs worked against pedagogical change.
3. Clarity of the change	• Guidelines appeared to lack clarity. • Curriculum document was confusingly eclectic.
4. Practicality of the change in the school and the community	• External exams and new assessment initiatives were seen to retard pedagogical initiatives. • Too many changes occurred at the same time. • Other demands of teaching did not leave enough time.
5. Supports during the change	• Professional development was not well coordinated. • There was a lack of communication between curriculum writers and implementers. • There was a delay due to a moratorium. • There was no trialling of the new physics curriculum. • A sample teaching scheme upheld the status quo. • Structures and expectations in the schools did not support the innovations.
6. Personal costs to the teacher and the possible benefits	• Some teachers fell back on to familiar aspects. • Some teachers were unwilling to move out of their zones of expertise.
7. Personal disposition towards the change	• Amount of change required was too much for some teachers. • Change occurs gradually.

Table 7: Summary of emergent issues from interviews in this study corresponding with change factors from existing literature

9.3 Discussion on Teacher Change

In summary, most of the teachers who were interviewed felt that they did not make substantial changes in their pedagogy and did not move to the position suggested in the curriculum document. This was foretold by one of the writers who lamented that the document was going to be misconstrued because of lack of guidance and lack of trialling. Writer 2's quote is worth repeating as it captures the needs for successful implementation quite succinctly:

That's what I really feel sad about, is implementing something without these trials. We said that another thing we need were resources, teacher development, people actually appointed to go out and do that teacher development; that's their full time job. Those kinds of logical things got cut off. So that's sad really, you know because you always feel responsible in a way because people are going to judge this (curriculum document) by how they use it, when in actual fact this is like draft two, this should be the final draft. ... this should go for trial and then a final document. ... have advisers who have been trained in this, so they're a phone call away It needs a teachers' guide and we were writing this with the idea that there was going to be one. That's very sad. ... it (the document) needs some guidance, it needs some instructions, it needs something. (Writer 2)

9.3.1 Interpreting the lack of change

The comments of the ten teachers in the first year of implementation of the physics curriculum indicated that for many of them little change in their pedagogy had occurred. The majority of the teachers' comments fell in a negative direction with respect to the seven change factors for effective change given in Table 7.

The lack of change does not imply that the curriculum was perceived uniformly in an unfavourable light. In fact, the teachers identified different aspects of the new curriculum that they felt good about: the decrease in some topics in the content; the widening of physics education to include real world and societal aspects; and a more hands-on approach to learning physics. These aspects resonated with the beliefs held by some of these teachers. However, due to the reasons identified above, there was not much impetus or opportunity to change. Two teachers appeared to understand well the new ideas in the curriculum document; they both had time away from teaching as science advisers. A third teacher was involved in contributing at a physics in-service course and took the opportunity to delve further into some ideas in the new

curriculum, namely, the role of investigations. He had felt the need for the old curriculum to change and so welcomed the new curriculum. However, given school and assessment constraints, these three teachers still often taught traditionally with a few new activities included that were suggested in the new curriculum.

When the teacher change issues from the interviews with teachers' implementing *Physics in the New Zealand Curriculum* were aligned with the change factors highlighted in the literature review in Chapter 2, the seven change factors identified in that chapter overarched the twenty-one emergent issues. This correspondence shows that the teacher change issues exemplify key dimensions (i.e., the seven change factors) that need to be considered when theorising teacher change in general, and the New Zealand physics curriculum change in particular. These are the factors influencing pedagogical change that need to be attended to by curriculum developers in order to successfully facilitate a curriculum change.

The next section takes the discussion a step further to bring about a synthesis of the factors discussed and melds them down to three core or key elements that need to be considered when wanting to bring about any real change in teachers and their pedagogy within a curriculum document-driven situation.

9.3.2 Three key elements for teacher change

From a sociocultural point of view, in the present context of a curriculum change, the artifact (reification) is the curriculum document (refer section 3.2). As the examples of barriers to change in section 9.2.3 and section 9.2.5 indicate, lack of communication between those in the development process of the document and those involved with the implementation of the curriculum denies access to teachers of a greater understanding of the document and the change involved. Teacher access is not just in the using of a curriculum document but also in the understanding of the underlying issues forming the basis of the document. With access to a deeper understanding, teachers could become more autonomous with respect to the change and its meaning, and this could lead to better informed participation.

Kennedy (1986) too suggested that greater understanding could be achieved when there is communication links between those in the development process and those in the implementation process of new curricula:

If we knew a little more about the events that took place while a product was being designed, we might appreciate the product itself much more. It would be useful if all new curriculum products incorporated a brief account of the design process, since some insight into the mind of the designer might well provide greater understanding of the product that has been created. (p.x)

Classroom teachers can be considered as curriculum developers whether they come in at the beginning or at the end of the official process of curriculum development because essentially they develop the curriculum for their classrooms (see Schubert, 1986). Handing them a very detailed curriculum document, or sample scheme, only satisfies their immediate needs. There are deeper, underlying needs that have to be addressed so as to sustain a change. This may require giving teachers access to the processes and issues involved in the development of the document.

At the in-service course that was attended by the researcher, the physics teachers were interested mostly in *what* were the changes; especially with respect to what topics were in and what topics were left out of the new curriculum. There was also some sharing about *how* to put some of the ideas expressed in the document into practice. There was no discussion about the philosophy of the changes, the underlying ideas and beliefs; the *why* question about the change. The questions that were frequently asked by the teachers revolved around the ‘*what*’ and the ‘*how*’ issues about the change. Thus, teachers were addressing a need for knowledge of the change in the sense of *what* is the change and *how* to put it into practice, but it is further suggested here that there was a need for teachers to know *why* that change was necessary. Hence the first key element of change put forward is **knowledge** of the change; that is, there needs to be a deep understanding of the curriculum artifact (reification in the form of the document in this instance) regarding what the change is all about, and an appreciation within the community of practice of how it is to be utilised and why it should be utilised.

Secondly, for significant change to occur there is need for **support** by a teacher’s community of practice. This is understandable because change can rock the core of teachers’ beliefs. For example, Fischler (1994), in a study of physics teachers, found

that where a pedagogical change was suggested, teachers needed to re-evaluate their deeply held beliefs such as their conceptions of the nature of science, teaching and learning. "Presumably, a 'conceptual change' concerning the philosophy of science would be a necessary precondition for a pedagogical reorientation" (Fischler, 1994, p. 179). For such a fundamental change, teachers need to be able to talk to others involved in the change. There is the need for networking and support structures among teachers as they explore the change. As Bell and Gilbert (1996) found in their study, "giving and receiving support facilitated professional, personal and social development" (p.104). Ross (2004) describes the importance of support for teachers from school administration, from the principal and the larger school community, and stresses the critical role these relationships play in the process of reform. These relationships can form the support base for the continuity of change experiences of the teachers. Keiny (1994) identifies that reflection on classroom practice in social contexts is important for teachers' conceptual change: "Teachers' conceptual change occurs in two interactive contexts, in the teachers' actual practice and in a social context such as a reflective team" (p.244).

Even if teachers can see the meaning behind the change and come to believe in it, the conditions of work and school structures, assessment requirements, expectations of students, school, parents and even the wider community, must in some way be in line with, or at least adaptable to, the proposed changes. The example of Henry illustrates the need for community of practice support for individual change to occur. As a science adviser promoting the curriculum document, he had the time to study it in depth and was able to understand it better than the other busy teachers. However, when he returned to teaching after his stint as science adviser, he found it a struggle to remain with his new ideas because of the constraints and parental expectations of his new school. This is also illustrated by Danny who was quite a progressive teacher who had to retreat to more traditional methods of teaching when he changed to a school where that was the expectation of the students and the staff.

In these cases, further networking within the school and with the outside community would be necessary to ensure that conditions and structures support, or at least are adaptable to, the changes being suggested (see also political force in Fullan, 1999).

Thirdly, there is a need for **time**. Time has been described as "the currency of change" by Senge (2000, p.385). Teachers need time-out from the flurry of day-to-day teaching activities to make sense of the new curriculum and plan for change (see also Hargreaves, 1994). Ross (2004) in her study of reform, also identifies the value of time as a component in change. Almost every teacher in this present study mentioned the need for time in some way or another.

These three key elements for enabling profound change, that is, knowledge, support and time, are comparable with the three kinds of capital postulated by Bourdieu in his influential theory on the reproductive function of schooling (Bourdieu, 1986). Lack of knowledge of the 'what', 'how' and 'why' of the curriculum change corresponds to a lack of cultural capital. Lack of networking and support to break through isolation and connect with other teachers as well as the writers corresponds to a lack of social capital. Finally a lack of time to study the curriculum document, undertake professional development and inculcate new ways of practice corresponds to a lack of economic capital invested into teachers. From the perspective deriving from Bourdieu's theory, the Ministry of Education while being instigators of curriculum reform in this research, did not ensure that teachers benefited by sufficient input of the various types of capital required for rapid and radical curriculum reform.

Any educational change attempt benefits from the insights obtained from theories of education and theories of change of action (Fullan, 1999). Fullan suggests that without the incorporation of theories of change, "...many reformers with well worked-out theories of education are non-plussed to find their valuable ideas are ignored or misused in practice" (p. 20). Change can be facilitated by the examination of the pedagogical assumptions and incorporation of strategies to guide and support implementation (Fullan, 1999).

Fullan (1999) explicitly outlines three dimensions for educational reform: intellectual, political and spiritual forces. According to him, the power released in the fusion of these three forces interacting and combining will lead to maximum effect. In his analysis, having quality information (intellectual), effective interactions within and outside the school (political), and moral purpose (spiritual) can enable teachers to become key players in educational change. These forces: intellectual, political and

spiritual, can be aligned with the three key elements suggested in this thesis for profound change: knowledge, support and time respectively.

Change is a complex situation that is always present; our rapidly changing society impacts on schools and there is pressure on teachers to be able to change their pedagogy to keep up with these trends. Elliot (1998) describes how a radical shift in the established culture of teaching and learning is required as a response to the changing nature of society. As with educational change in general, changing pedagogy is not an easy task because it involves a re-evaluation of basic beliefs and accustomed practices (see Davis, 2002). A theory of pedagogy that extends into pedagogical change can highlight the need for teachers to nurture the capacity to change, while reflecting on the basis of their current pedagogy and that of the proposed pedagogy in curriculum changes. Developing theories of pedagogical change is important if we are to fully comprehend the reality of how educational practices change.

9.4 Conclusion

This chapter drew together the research data and the theory around teachers undergoing change. The list of seven change factors derived from the existing literature (see section 2.8, that considers the analyses of Fullan, 1991; Doyle & Ponders, 1977; Waugh & Punch, 1987; Lee, 2002; Jones, 1999; and McGee, 1997, amongst others) was found to be helpful in subsuming the twenty-one issues that emerged from the research data. Based upon the data collected in this research, the seven-factor list is put forward as a valid set of criteria in planning or analysing teacher change.

Viewing change as a sociocultural product and drawing on the theories of Bourdieu and Fullan, as well as the voices of the teachers and writers in this study, I went on to argue that the three key elements that enable teachers to make informed judgements and attempt a real change in their classrooms are:

1. **Knowledge:-** ‘what’, ‘how’ and ‘why’ of the change. (Teachers in this study were still grappling with the ‘what’ aspect even towards the end of the first year of implementation.)

2. **Support:-**

- a) networking among fellow teachers and facilitators of the change including the curriculum designers. (Teachers in this study said that they had to make sense of the document mainly on their own with insufficient professional development on the new curriculum.)
- b) adaptability of systems and structures to the change. (For example, assessment procedures that are not adaptable to the aims of the suggested curriculum can undermine its implementation.)

3. **Time:-** time out from teaching to focus on the change. (Even after four years of the publication of the *Physics in the New Zealand Curriculum*, some physics teachers said that they still had not read it in full.)

It is suggested that the predominance of these three elements is likely to influence how successful a teacher change initiative is likely to be. These elements of knowledge, support and time are the resources that can lead to sociocultural change in a community of practice. It follows that when a teacher change initiative is planned, as well as planning the delivery of new ideas, teacher development should include planning the process of change for teachers in terms of the three key elements I have identified (discussed also in Fernandez & Ritchie, 2003).

The next chapter, Chapter 10, will look at the broader picture of curriculum change and the place of teacher change within that scenario. Many researchers have written about the centrality of teacher change in bringing about a curriculum change. The wider picture of curriculum change, including the role of the teacher in that process, is analysed using Wenger's (1998) notions of reification and participation.

Chapter 10 ➤ The Curriculum Change: A Sociocultural Analysis

10.1 Introduction

Teacher change as discussed in Chapter 9 was a fundamental issue in the wider picture of a curriculum change. In this chapter, the curriculum change in physics that was enacted in this research is analysed making use of the sociocultural perspective put forth by Wenger.

Wenger's (1998) concepts of community of practice, participation and reification (see Chapter 3) provide a useful framework for analysing the design and implementation of a new mandated physics curriculum in New Zealand. The contracted curriculum writers considered the Ministry's writing brief, current best teaching practices, their own views as physics educators, the views of stakeholders such as the Institute of Physics, submissions from teachers, and comments from the Review Committee and the Reference Group; and then they reified these ideas into several draft curriculum documents and subsequently wrote the final *Physics in the New Zealand Curriculum* document.

Teachers were required to interpret the document, internalise it, and use it as a frame of reference for their new teaching programmes. Teachers' further participation involved reification of the ideas underlying the curriculum into schemes of work and assessment tasks and schedules. They then participated, utilising these further reifications in translating the ideas into actual practice in the classroom. In the classroom they faced constraints, supports and other factors that were enabling or disabling of the implementation of the curriculum intended by the writers.

Some teachers were helped by the participation of other teachers in their community of practice as they engaged in the process of interpreting the curriculum document; other teachers contended with it on their own. The perspective taken in this chapter suggests that the sense that a teacher made of the document was related to the amount of shared cognition (understanding) existing between the architects of the document

and that teacher. The writers were physics teachers who originally came from the community of practice of the implementing teachers. That undoubtedly contributed a degree of shared understanding of what was involved in teaching senior physics at schools, which was reflected in the new curriculum document. One experienced high school teacher commented that without much previous experience, trainee teachers found it hard to make sense of the extent and depth to be covered for the various topics given in the document:

When I got the document I was very comfortable with thatWhat really moved me from my comfort zone was I used to have a lot of beginning teachers from the training college come and work with me.... OK they go out and prepared some work and they continually come back and say “I don't understand what I have got to do; what sort of things”, and I realised that ... the only reason that I felt comfortable with the document was my experience. (Henry)

The writers were not the only ones involved in the reification process of producing the curriculum document. As highlighted by Bell et al. (1995), in drafting a curriculum there are inputs from multiple stakeholders. Thus even for experienced teachers, the input from other stakeholders incorporated in the curriculum document would make it difficult for them to interpret all the layers of meaning the document contained. The writers could see the bigger picture and knew the way in which the different ideas and inputs had been incorporated into the document. However to convey a deep understanding of the many layers of meaning required more than just the mediation of the curriculum document and participation with other teachers. Ideally it would have required the additional mediation of the writers themselves.

The writers, though originally from the same community of practice as the other physics teachers, had grown and been extended in their ideas about physics teaching in the writing process. They may have grown apart from the original community of practice in the sense that they had other ideas that were not amongst the shared meanings of most other physics teachers. This is not to deny that the writers still retained a lot of overlap of shared meanings with the physics teachers:

We were successful physics teachers who were producing new stuff and a fair degree of innovations still with a fairly strong practical orientation towards physics too. ... We had a wide range of experiences ... but it was largely a passion for teaching physics, for switching kids on to thinking, getting them able and confident in their investigating, and to look at things that happen to

them in everyday life from the physics point of view as well as normal, ...
(Writer 1)

The following comments from the writers exemplify their shared sense of identity and growth as a community of practice, quite separate from that of other physics teachers:

... the three of us were quite similar, almost interchangeable and we grew together in that respect too. ... the three of us were constructivists in the sense that we are interested in how the kids are learning. I think that is the key similarity we have that not all other teachers have, and we would see that as an aspect of good teaching. (Writer 1)

... we all came with different experiences and we all came with different beliefs and ideas, and together we learnt a heck of a lot from each other. Oh it was so wonderful. I really miss the sessions we used to have. We learnt so much from each other about teaching and learning. (Writer 2)

... we had countless three hour meetings just talking and talking and reading and talking. And I think we had sorted our own philosophy out in the course of that ten week period and we were really lucky as a working group in that our philosophies just gelled. ... So we had a stronger sense of what we were about and why we were doing it. (Writer 3)

Teachers had to make sense of the final curriculum document's statements, in order to incorporate them in their classroom practice. For many of the teachers interviewed, it became mere paper work where new schemes of work were written and new assessment schemes were incorporated but essentially their physics lessons remained the same (see section 9.2.7).

To summarise, for these teachers, in its initial implementation phase, the new curriculum did not lead to the teachers engaging in significant participation in a community of practice focused on the intended innovations. Indeed, McGee et al. (2003) found that this situation of limited teacher change appears to have endured, as over two-thirds of a sample of senior physics teachers responding to a recent Ministry of Education curriculum stocktake were not using contexts to teach physics. (The contextualisation of physics in teaching was an innovative element of the new curriculum with suggested contexts provided at each achievement level in the document.)

10.2 Applying Wenger's Framework to Curriculum Change: Introducing the Term "Dereification"

This thesis has drawn on Wenger's (1998) social theory of learning, utilising the definitions of participation and reification, to describe the development and implementation of a new physics curriculum in New Zealand. Wenger's (1998) book contains very detailed descriptions, explanations and expansions of his theory. Extensive though it is, it was found useful to add to Wenger's ideas for the purpose of theorising some aspects of the curriculum change and teacher change processes in the case of the physics curriculum in New Zealand secondary schools.

The point of focus in the physics curriculum change described here was the curriculum document, *Physics in the New Zealand Curriculum*. This artifact developed by the curriculum writers encompassed far more than the words on the pages. In terms of Wenger's metaphor, the curriculum document is the 'tip of the iceberg'. The following comment from one writer highlights the hidden understandings that were depicted in the document by single statements:

They (the achievement objectives) are almost the most meaningless little statements in the whole document which had the greatest number of hours spent over trying to get them right. (Writer 3)

The curriculum document is a reified artifact which is a product of the partially shared meanings held by writers and stakeholders (e.g., Ministry, reference groups, Institute of Physics, etc.) involved in the development of the document. However, the writers were aware that the words in the curriculum document alone could not give a full picture to the community of physics teachers:

They (Achievement Objectives) are a reflection of the fact that if you want to make a short sentence sufficiently generalised so that it covers every case that you could want to talk about, then you can do that but the price you will pay is to make it totally meaningless. ... you could read this and think "so what do I teach?" (It) doesn't actually help. (Writer 3)

Wenger (1998, p. 186) suggests that, in general, reification "affords an opportunity to step back and see situations in a different way. ... it allows rearranging the world and dislocating experience". The writers' reification of physics education in the form of the curriculum document was intended to afford just such a rearrangement and change

in the way of viewing physics education. New ideas and new identities were suggested and teachers could use their imagination and experience to grapple with these. Thus the curriculum document was a form of ‘communication artifact’:

A design, then, is not primarily a specification (or even an underspecification) but a boundary object that functions as a communication artifact around which communities of practice can negotiate their contribution, their position, and their alignment. (Wenger, 1998, p. 235)

The writers were aware that, as well as meanings they shared with most other New Zealand physics teachers, they had incorporated new perspectives that were not shared by the majority of physics teachers. They felt that there was a need to help the physics teachers to share in the writers' understandings, because if teachers were dealing with the curriculum document alone, they were likely to misconstrue and/or reject what was written in the document (see quote by Writer 2 on page 250).

There are parallels between the external reification in this case of curriculum development and the case study of insurance claims processors given by Wenger (1998):

In an institutional environment such as a claims processing site, a very large portion of the reification involved in work practices comes from outside the community of workers. Even so, however, reification must be re-appropriated into a local process in order to become meaningful. (p. 60)

In New Zealand schools, after the development of an externally reified object in the form of the physics curriculum document, science advisers and teachers participated in trying to re-appropriate the meaning of the document for their local context, that is, their classrooms. Teachers had to make sense of the document and then write new teaching schemes. For Wenger, this process would be a form of participation and reification.

The duality of participation and reification, though of value to look at processes within communities of practice in general, has limitations in terms of explaining the curriculum change situation in our study. In particular, it does not provide a particular theoretical term to describe the activity that was occurring after the curriculum document was produced and distributed to schools. During this period of time, there were intense interactions that focused on the document. The interactions were of a

personal nature as well as a social one. Such interactions are forms of participation that have been described in a number of ways by Wenger including re-appropriating, interpreting, re-negotiating meaning, realisation of a prescription or description. Participation, however, is also linked to the reification process where the people within a community participate together in the process of reifying some aspect of their practice. In these terms, participation can be seen as being present at every point in the development and implementation of the new physics curriculum.

The axiomatic concurrence of reification and participation set out in Wenger's sociocultural theory suggests that to participate is always to reify. This might be taken to imply that when implementing a curriculum, teachers participate and reify in much the same way as the writers of a curriculum document participated and reified to produce a reified object (the curriculum document artifact). However, the participation of writers and teachers in curriculum development and implementation can be seen as different in kind. In curriculum development, the main goal of the curriculum writer is to arrive at an artifact in the form of a publicly shared curriculum document. In contrast, for the teachers implementing a new curriculum, the main goal is to arrive at a coherent scheme of practices that are connected to the goals set out in the curriculum document.

A new term **dereification** is introduced here to describe the participatory process occurring when members of a community of practice move from just following the surface rules associated with a reified form towards actually accommodating the reification into their practice cognitively, emotionally and socially (see Fernandez, Ritchie & Barker, in press). For the teachers involved in this study who were implementing a new curriculum, this was a stage of intense interaction, where a prior object of reification, the curriculum document, became meaningfully included in the teachers' practice.

The term "dereify" though new to Wenger's theory has appeared in sociological literature (e.g., Berger and Luckmann, 1966). The meaning of the term 'dereification' may vary with social theory. While the sociologist, Schutz, did not use the term 'dereify', Thomason (1982, p. 90) points to a passage in the writings of Schutz that suggests that objectivities are able to be unfrozen and returned to their original active

state. Such a view of dereification while consistent with constructionist traditions differs from the social theory of learning-oriented definition advanced here.

The process of dereification advanced here can be considered as the reverse process to reification (in that an artifact becomes realised in practice whereas reification is the result of practice being encoded in an artifact). Thus for a teacher, dereification is a particular form of participation where there is intense interaction with the reified object leading to a form of tacit, "non-articulated" practice which is compatible with the teacher's personal and professional identity as well as their social context. For example, Danny who had previously experienced difficulty with the amount of time required in contextual teaching, this led to his conscious adoption of a particular focus for context:

I'm not putting much emphasis on influences of everyday physics applications on lives, in particular, exploring the experimental evidence in developing theories...Certainly in terms of techniques in investigations, yes, I'm doing that; but I was reading that as sort of an historical context. I am mentioning it, but certainly not putting much emphasis on it; certainly not getting into long-term running investigations. (Danny).

The research literature on how teachers' prior beliefs impact upon teacher development indicates how little impact the prescribed curriculum may have on teacher pedagogy and how important teachers' implicit beliefs are to their practice (e.g., Claxton, 1989).

The definition of *dereification* that is being extended at this stage is that it is *a process where the reified object is incorporated within the plane of lived experiences and thus loses its purely objectified status*.

Lave and Wenger (1991) see participation in a community of practice as the key unit of analysis in a theory of social practice that includes learning. In this research analysis, participation is seen as being involved during dereification as well as during reification. For example, Cathy described how in utilising the curriculum document, she and other teachers compared it with (exam) prescriptions, and a school scheme developed by a group of South Island teachers:

There were lots of things in there that we were doing already, and every now and again, we'll say "so how can we best do this", or "looking at where we're

at now and time constraints, what should we do?"...But really there were three things there (document, prescription and sample scheme) and they all tie in very easily to each other. It is not that we use one thing as the basis. (Cathy)

Participation and reification form a duality according to Wenger. In the model advanced here, participation and dereification are seen as also forming a duality; and reification and dereification are considered to be a dichotomy rather than a duality. Figure 5 illustrates the relations inherent in the structure of this model.

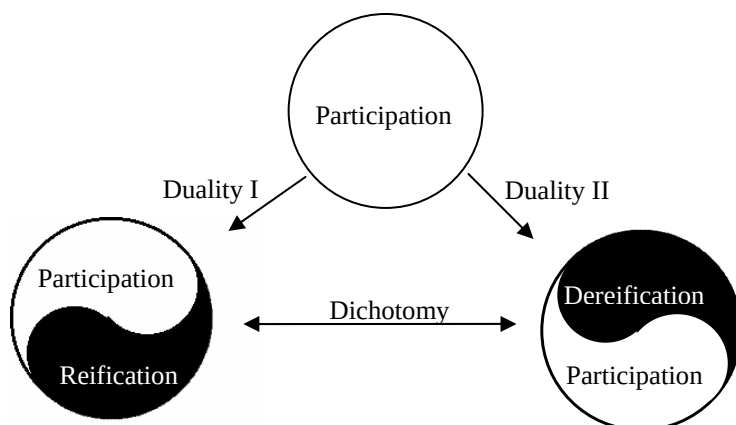


Figure 5: Reification and dereification subsumed within participation

The theoretical framework comprising participation, reification and dereification has been useful in analysing the development and implementation of a new physics curriculum. The dichotomy of the processes of reification and dereification was found to be necessary in developing a model of curriculum change based on this theoretical framework.

10.3 Theorising Curriculum Development and Implementation - A Wenger-Based Model

Using the extension of Wenger's theory, a model was developed of the curriculum change processes that occurred in the development and implementation of the new physics curriculum in New Zealand. The model is an abstraction of the practices underpinning the whole process of changing the New Zealand physics curriculum and as such is subject to the same caution that Bourdieu (1992) gave regarding one of his models:

The diagram and all oppositions, equivalences and analogies that it displays at a glance are only valid so long as they are taken for what they are - logical models giving an account of the observed facts in the most coherent and most economical way; they become false and dangerous as soon as they are treated as the real principles of practice, which amounts to simultaneously overestimating the logic of practices and losing sight of what constitutes their real principle. (Bourdieu, 1992, p. 11)

This model of curriculum change would seem to be more transferable to examples of mandated curriculum development and implementation rather than non-mandated ones where the effects are less stark. An additional example of the former is found in the mandated reforms described by Morris (2002). Examples of the latter are found in teacher development projects such as those described by Baird et al. (1987), and Bell and Gilbert (1996) in which changes in teacher pedagogy were voluntary and the impetus for change came from within the teaching community.

A general cycle of mandated curriculum change advanced here is shown in Figure 6. Here, the writers of the curriculum develop a document which is interpreted by teachers to design their new teaching schemes and teach their physics lessons. Over time this in turn leads to what is the normative or paradigmatic practice of teaching physics. When the next round of mandated curriculum changes are initiated (about every ten years in New Zealand), the writers will work within the realm of the existing normative practice yet extend it to cover best contemporary teaching practice and other innovative and recommended ideas.

The curriculum document is a reification of what the writers intend that physics teaching should encompass: intended normative practice and its underlying theory. The intention of the curriculum developers was for the curriculum document to become the mediating object for the development of progressive normative practices.

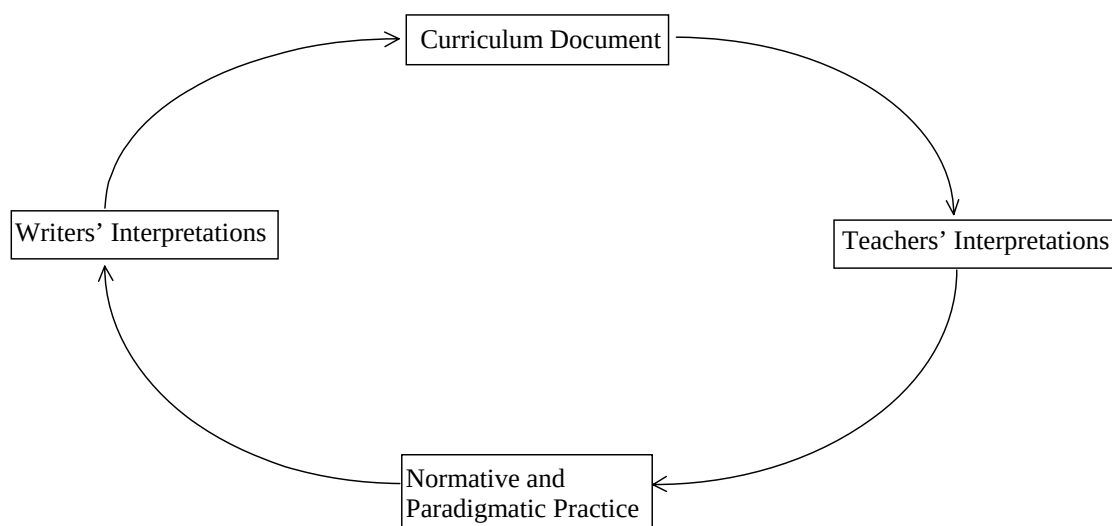


Figure 6: The general cycle of mandated curriculum change

There are two extreme responses to this where the ideas encompassed in the document might be merely assimilated into teachers' existing schemas, or a radical shift might occur with a teacher having new conceptions of what is normative practice (much akin to accommodation as described by Piaget, 1970).

A fuller representation of the model incorporating Wenger's term of reification (R) and the new term, dereification (DR), is given in Figure 7 to describe the processes in the curriculum change cycle. Very often, a period of reification (R) leads on to a period of dereification (DR) and then on to more reification (R), and so on with some degree of overlap at every stage. As shown in Figure 7, the curriculum writers reified ideas about best practice and normative practice in physics education (working within the given curriculum framework and writing brief) in writing the curriculum document (R). Teachers were then involved in interpretative and discursive processes (working within the context of their schools) so as to dereify the document, resulting in new ideas being put into practice (DR). However, the curriculum as designed cannot ultimately determine the final form of practice as “there is an inherent uncertainty between design and its realization in practice, since practice is not a result of design but rather a response to it” (Wenger, 1998, p. 233). The physics curriculum document had an intended design but each teacher’s response to the document determined their actual practice.

Teachers, having dereified the document (the 'tip of the iceberg', see Figure 1), brought it to work within their plane of lived classroom experiences. Teachers' interaction with the document, however, did not stop at the initial phase of fluid practice. They used their understanding to develop objects (R) such as schemes of work, lesson plans and assessment schedules.

These objects were then used to guide actual classroom practices (DR) which then resulted in further objects such as students' work, reports, assessment results etc. (R). Teachers and pupils reviewed these artifacts and used them when reflecting on the process and outcomes of their teaching (DR). An example of a teacher reflecting on his teaching programme at the end of the year is given below:

On reflection, we looked at what we were going to remove last year when we wrote the programme for this year and in our scheme we put a lot of things in italics. ... We went through the new document and looked at what we were presently doing, having them side by side. We decided that everything that wasn't in here (the document) we put in italics and say that they are optional ... So having gone through this year, I found it quite difficult to complete the course because of the content and a few extra bits and pieces, I suppose, that we put in as well and yet we weren't moving enough stuff out. ... we started to cut little bits out because of time, but if you look at our assignments, a lot of stuff is still in the assignment work, and I say it shouldn't be. (Henry)

Figure 7 contains two 'suns' to indicate that there was a focus of institutional processes, at both a national level (the Ministry of Education) and at a local level (the school), that conditioned the processes of reification (R) and dereification (DR) depicted in the model.

Although the linear nature of textual expression has shown the processes as a series of stages, in reality, there is a degree of overlap of the stages. In the cycle around the Ministry, that is, the processes involved in the development of the curriculum document, the processes of reification and dereification alternated in the writing of drafts and the review process. This series of processes is particular to the curriculum change studied in this research. The cycle was traversed a number of times before the final curriculum document was published. The sequence of production of drafts and reviews may vary in other curriculum change initiatives.

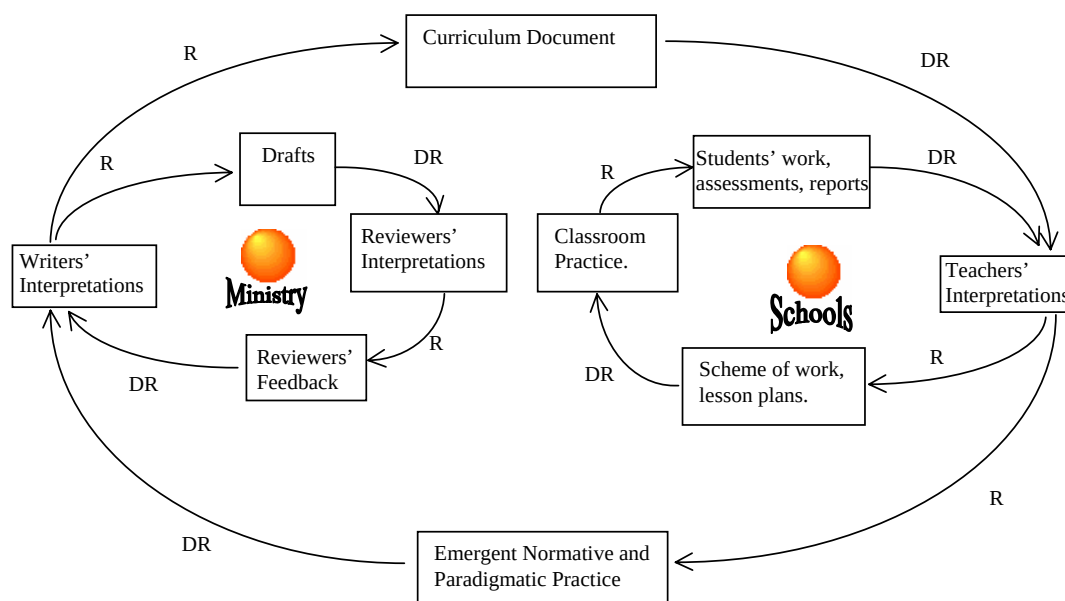


Figure 7: The curriculum change model showing component steps involving reification (R) and dereification (DR)

The cycle of change processes at the school level involving teachers is more standard. Here, teachers dereify the curriculum document and bring into the process their response to the design based on their background, beliefs and circumstances. This response is reified into their teaching schemes and lesson plans which is then dereified into their classroom practice. From their practice of teaching, reifications in the form of students' work, assessments and reports evolve. The revision of lesson plans by teachers when reflecting on their teaching programmes may provide the stimulus towards incorporating more of the changes suggested in the document for the following year. Such a cycle is an annual one, although some teachers do modify and change the course of their programme sometimes during the year:

I am going to plan some more changes; I am still not sure what. I am so snowed under with other things right now ... that would be one of my holiday things to do ... again it is a constant situation of subtle changes rather than, you know, large ones. (Jack)

It is likely that most teachers traverse the change cycle a few times, progressing a little each time till they have settled to a comfortable response to the new curriculum document. Supported by participation in their community of practice, this process may result in a teacher adopting as their practice, the practice characteristic of most physics teachers in secondary schools in response to the new curriculum. That

participation process and its endpoint are constitutive in a teacher gradually developing a new or modified identity of being a physics teacher:

Ways of classifying human beings interact with the human beings who are classified. ... Classifications do not exist only in the empty space of language, but in institutions, practices, material interactions with things and other people. (Hacking 1999, p. 31)

People classifying themselves as physics teachers think of themselves as of a kind. However their interactions with artifacts and other people can result in modification of behaviour and practice. Hacking (1999) calls this the “looping effect” where:

what is known about people of a kind may become false because people of that kind have changed in virtue of what they believe about themselves. (p. 32)

This modification of behaviour and practice on a wider basis in the community of practice constitutes the rise of a different normative practice for the community of physics teachers. This is shown in Figure 7 as a stage that can come about after the cycle of reification and dereification in the schools has been traversed a number of times.

Putting the parts of the processes that are being described here together, the whole of the curriculum change process is represented in Figure 8. One addition to the model is the acknowledgement of macrosystem and exosystem elements (as defined by Bronfenbrenner, 1979). Thus the full model also acknowledges the influences of a number of social structure agencies which mediate the influence of cultural elements such as legal principles, and belief in the value of science, etc.

A second additional aspect of Figure 8 is the presence of a screen separating its two sides. In the development and implementation of the New Zealand senior school physics curriculum there was very little dialogue between the writers of the curriculum document and the implementers of it post-publication. The presence of the screen in the model depicted in Figure 8 denotes the communication chasm between the developers of the curriculum and the implementers of the curriculum. In-depth discussions amongst the curriculum writers had to be reduced to one-liners in the document, and teachers were not made aware of the issues discussed and the underlying ideas and philosophy supporting the physics curriculum document.

From a sociocultural perspective, Lave and Wenger (1991) describe how there was a need to open up the 'black box' of an artifact (or cultural tool) so that the inner workings are available for inspection:

Obviously the transparency of any technology always exists with respect to some purpose and is intricately tied to the cultural practice and social organisation within which the technology is meant to function. ...this notion of transparency constitutes the cultural organisation of access. (p. 102)

Although there was opportunity for teachers to feedback comment on the draft, this did not provide opportunity for the curriculum writers to reveal what were the fundamental purpose, philosophy and considerations in the draft itself. Dereification of the draft seems to have been taken as unproblematic by the Ministry of Education.

Thus, for the ordinary classroom physics teacher, there was only a chance to comment on an initial draft curriculum document; and that draft document itself was seen as all the information required for that process to occur. This limited consultative process is the screen (in Figure 8) obfuscating the discourses of the curriculum developers and those of the teachers. While the curriculum document that emerged was intelligible in terms of the semantics of the meanings associated with the individual words in the document, it was in fact an object peripheral to the 'expanses of meaning' of the community of practice that teachers were located within. As such it did not become an object of discourse and exploration in the consciousness of the teachers during the time leading up to curriculum implementation. In Wenger's terms (see Chapter 3), the meanings in the document were not contestable within the dominant economies of meaning; there was no real brokerage involving the writers of the new curriculum in bridging between the community of practice of the teachers and the various communities of practice as stakeholders consulted by the Ministry of Education.

When teachers interacted with the curriculum document to utilise it as a guide to their practice, because they did not have the background to the suggested ideas, they were in a similar situation to a neophyte reader without a background understanding of a writer's intended meaning (see Northedge, 2002).

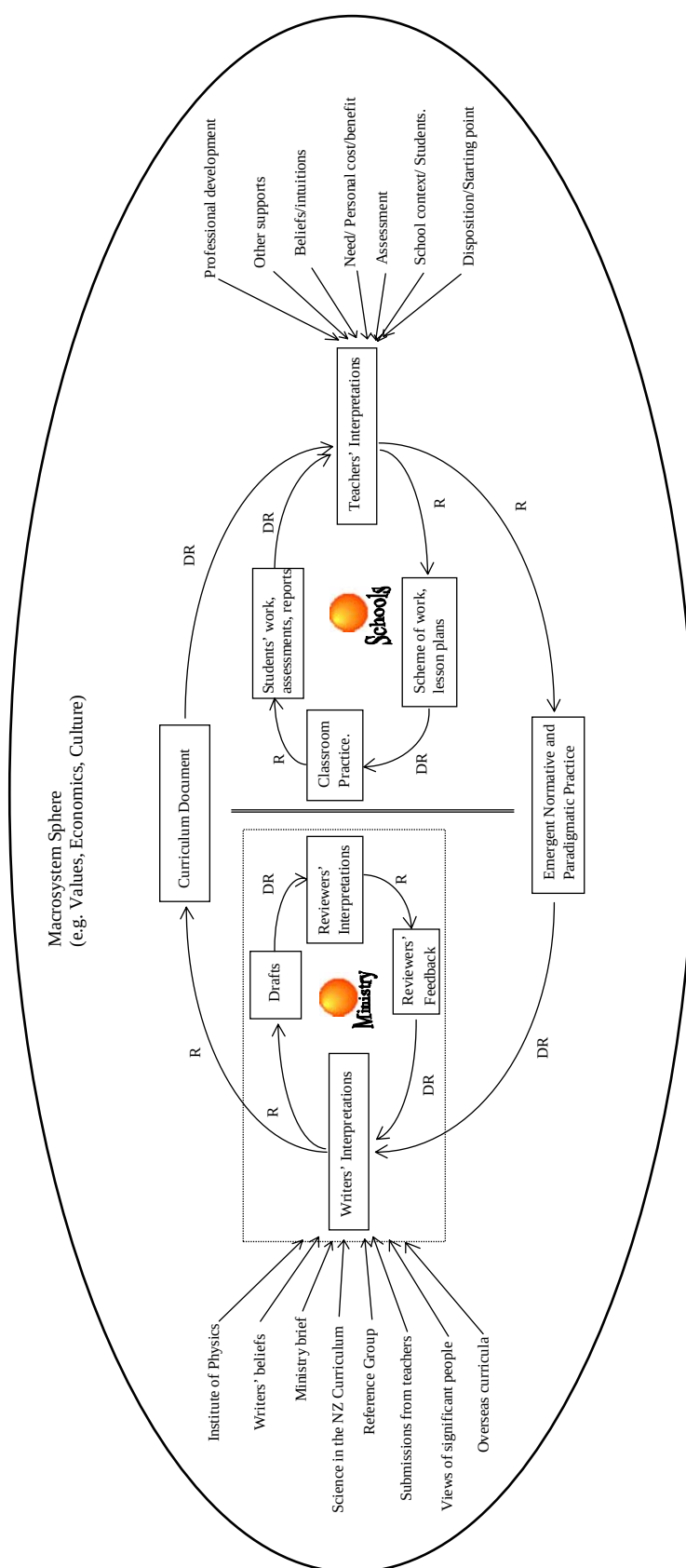


Figure 8: The model of the development and implementation of *Physics in the New Zealand Curriculum*

Thus, because the teachers and curriculum writers did not share ideas, the teachers gained little help in the process of decoding and comprehending the text when they were reading the document. The teachers were not privy to the in-depth discussions that the curriculum writers had. The writers' views had been consolidated and modified by their readings and discussions. Understandably, without access to this discourse, some ideas in the new curriculum were not shared, understood nor accepted by the teachers. For example, Andy referring to ideas in the document stated:

We are in the danger of this (contextual teaching) taking over a little bit but fortunately I think most physics teachers are kind of resistant and have their finger on what is truly important, and I am not sure where all this comes from. (Andy)

Lave and Wenger's (1991) notions of the 'visible and invisible' are also relevant to understanding teachers' responses to the document. The curriculum document can be considered a window through which the writers rendered the world of school physics visible. Most of the aspects captured in the writing are the obvious or visible aspects of physics teaching. Almost invisible in the document are the traditions and aspects of the subject discipline that are taken for granted as existing among the community of practice of physics teachers. However it is the invisible, such as the pedagogy for teaching physics most expediently, that plays a pivotal part in dereification of the document and the development of intuitive teaching practice (Atkinson & Claxton, 2000).

The curriculum writers said that they wrote from a teacher's perspective, but it was a progressive teacher's perspective. While the document was not intended to be prescriptive, it inevitably privileged a particular perspective on physics education:

I think our common approach to teaching physics is a moderately energetic one ... All three of us are quite experimentally orientated ... we were in the stage where we were confident teachers. ... Our ideal idea of teaching is very interactive with kids, and puzzling over things; being prepared to say "can't understand that", "don't know", "I'll find out", or "what do we think could be happening?" (Writer 1)

In the terms used by Wenger (1998), teachers were provided with the curriculum document, a product of the processes of reification, and then they made sense of the document within their communities of practice. While communities of practice seem to be referred to as if they were physical entities, some physics teachers were more on

the periphery and isolated at the time they were interpreting the document. They were, however, tied to a community of physics teachers with which they identify because of common histories of participation (e.g., university study, physics teacher education) and common reifications (e.g., common external examinations). So the dereification of the physics curriculum document was a situation quite different from one in which a curriculum document is responded to by physics teachers in dialogue with the authors of the document. If there had been such a dialogue with the curriculum writers, teachers would have had more access to their ideas about science and physics and to the underlying philosophies leading to the curriculum document. They would then have had the frameworks to carry out the intended dereification in practice of the curriculum document. While it is acknowledged that there can be more than one meaningful dereification in practice of a curriculum document, however, the argument advanced here is that having dialogue with the writers as suggested, the teachers would have been in a better position to recapture the writers' intended meanings in their dereification discourses.

10.4 Conclusion

The development of the model in Figure 8 brings together the empirical in the form of interview data and the philosophical and psychological groundings of sociocultural theory. The model, an abstraction of the lived experiences of the interviews in the present study, illustrates the ongoing cyclical processes of curriculum development (as described by the writers) and curriculum implementation (the experiences of the teachers). Although the model owes much in its specific formulation to the scholarship of Etienne Wenger, it can still be claimed that it follows from the whole sociocultural approach to teaching and learning:

- It views knowledge acquisition as a collaborative and socialising practice.
- It conceives humans (here curriculum writers and teachers) as operating in communities of practice.
- It centralises the role of artifacts or cultural objects (here the curriculum document) in mediating action within a social setting (includes cultural, institutional and historical settings).

This chapter used an extension of Wenger's ideas to analyse the situation of the development and implementation of a new physics curriculum in New Zealand

secondary schools studied in this research. The model developed here was found useful in laying out the processes involved in such a mandated or top-down curriculum change. The processes were highlighted with the use of Wenger's term of 'reification' and an introduced term of 'dereification', both of which constitute 'participation', as defined by Wenger, in this situation. The model highlighted that without the brokerage of meanings between the writers' and teachers' communities of practice, it is only the "tip of the iceberg" that is apparent to many of those implementing a new curriculum. Under such conditions, the dereification of a mandated curriculum is prone to lead to only minor changes in pedagogical practice.

The next chapter, Chapter 11, concludes this thesis with summaries of the answers to the research questions, limitations of the research, implications and conclusions. The conclusion of Chapter 11 will suggest the value of overlaying the ideas on effective teacher change discussed in Chapter 9 with the Wengerian analysis of curriculum change in this chapter.

Chapter 11 ➤ Conclusions and Implications

11.1 Introduction

This thesis has worked from an interpretive paradigm in terms of research strategy and adopted a sociocultural theoretical framework for analysis. From those methodological and theoretical boundaries, this thesis set out to answer the five research questions listed in section 3.4. As with much research, the answers that emerged were not as definite as the questions asked and the process followed is more one of ‘unearthing’ rather than one of arriving at the ‘truth’. Furthermore, the unearthing that occurs includes the appreciation of limitations as well as the appreciation of new insights. The findings of this thesis concerning the original research questions are set out in section 11.2. Section 11.3 discusses some of the limitations in the research and questions that need further research. Section 11.4 considers the implications of the research for curriculum design and implementation. Section 11.5 is the concluding commentary of this thesis.

11.2 Research Findings

In terms of the research questions posed in Chapter 3, a summary of the main findings associated with each question is set out below.

Question 1: Viewing the curriculum as a cultural artifact, how was the new physics curriculum developed?

How the new physics curriculum was developed was explored in Chapters 5 and 6. They indicate an intense writing process with dialogues occurring between the writers, the Ministry of Education, and various other interested parties such as the Institute of Physics. Overarching all of these discourses was a political imperative that dated as far back as the Minister’s promises of educational reform in 1989. What emerged was *Physics in the New Zealand Curriculum*, a document that, in spite of its many compromises, the curriculum writers hoped would lead to change. The writers developed a document that conformed to the neo-behaviourist framework of levels and achievement objectives, but allowed for more social constructivist ideas of

pedagogical innovations, contexts and contents relevant to students in New Zealand schools.

Question 2: What were the teachers' interpretations of the document and how did they interact with the curriculum document and arrive at these interpretations?

The evidence around this question was explored in Chapters 7 and 8 that presented the data obtained in three interviews over three years with teachers implementing *Physics in the New Zealand Curriculum*. The teachers' interpretations of the ideas reified in the curriculum document varied as did their attitudes towards the changes suggested therein. Some viewed the more contextually-oriented, investigative, conceptually-focused, socially-oriented, self-reflective elements in evidence in the new curriculum as detracting from students' learning of basic physics concepts. Others had a different view and believed that the mentioned elements were the key to developing a deeper understanding of physics in the learner. The evidence provided in Chapters 7 and 8 showed that amongst those with attitudes supporting the ideas of the new curriculum, there were teachers who considered that they had made negligible changes in practice in the first year of implementation. On the other hand, two teachers viewed the changes that they had made in their practice as significantly in the direction of the new curriculum.

All of the teachers in this study viewed the way that they taught physics in the first year of implementation as complying with the requirements of the new curriculum. For most this involved relating their current school scheme to the content and achievement levels in the document (i.e., re-labelling). Thus the interactions around the document were either those of compliance or taking it up as a blueprint for major change.

Question 3: What were the factors that enabled or hindered implementation of the new curriculum?

Chapter 9 illustrated that each of the change factors, collated from the literature review and synthesised into a list (see Chapter 2), was identified by the teachers as a barrier to change when it was absent. Chapter 9 also condensed the list of change factors to identify three key elements as being the capital of change: Full in-depth knowledge about the change; the support of colleagues and school structures to allow the social transformations underlying the change; and time to reflect and develop in

the direction of the change. The description in Chapter 8 of Henry, one of the teachers trying to effect genuine change, illustrated the change value of these elements. For many of the other teachers, these change elements were absent and they viewed themselves as not having effected significant change in the first year of implementation of *Physics in the New Zealand Curriculum*.

Question 4: Can a sociocultural perspective be used to analyse and provide insight into a situation of mandated curriculum change?

In Chapter 10, I systematically developed a model of mandated curriculum change utilising Wenger's sociocultural theoretical framework. The model emphasises the development of, and interactions with, cultural artifacts (reifications). It is around these reifications that communities of practice organise their practice (participation). Mandated curriculum change turns out to be a particularly interesting situation to study as there is reification of curriculum artifacts occurring at one level of the Ministry of Education, and these reifications have to be interacted with in the world of the classroom. To emphasise the way in which teachers interact with such artifacts and, in their interactions, deconstruct them to become part of their lived classroom experiences, the term 'dereification' was developed. The complex model set out in Figure 8 of Chapter 10 illustrated that there are many processes of reification and dereification occurring in the negotiation of meaning that underlies the process of a mandated curriculum change.

Question 5: What are the implications of a sociocultural model of curriculum change for future attempts at curriculum reform?

This is discussed in section 11.4 in this chapter.

11.3 Limitations and Suggestions for Further Research

The study in this thesis on the development of *Physics in the New Zealand Curriculum* setting out a new senior schools' physics curriculum, and its implementation in schools focused on the insiders' perspectives, that is, that of the writers of the document and the teachers implementing it. However, it is acknowledged that there are many other stakeholders whose views could have shed further light on the situation being studied. Thus the limitation of this study, where the

views of the Minister or the Ministry's Policy Advisory Group and also that of the students were not included, suggests their inclusion in further studies.

The insiders' perspective is a very valuable source of data highlighting the voices not often heard and deeply held views not often aired, and thus it is the insiders' perspective that is a prime focus in this study. The danger, however, is that individual perceptions, being personal, may have nuances that are considered not accurate by the Ministry or others.

Following the focus on the insiders' perspective, this research did not conduct classroom observations; but it is acknowledged here that classroom observations could have been a good extension to this study and would have allowed further triangulation to what was being said at the interviews. Another possible extension is the development of a questionnaire based on the findings of this study to evaluate the nationwide impact of the curriculum change endorsed by the physics curriculum document.

The question of generalisability did arise in this study as it involved ten physics teachers in and around a provincial city in New Zealand and thus was not necessarily representative of physics teachers nationwide. The uncontroversial generalisation that can be made on the basis of this study is that some teachers found that they implemented *Physics in the New Zealand Curriculum* without changing their practice.⁴ The answer to whether the pattern of relatively insignificant changes found in this study has occurred beyond this sample of physics teachers should not be answered by the researcher's judgement. However, as explained in Chapter 4 and Chapter 7, the case studies and in-depth interview data presented a clear trail of the analysis so as to enable transferability judgements. Thus, comparisons and reflections can be made on the relevance of the descriptions in this thesis by other researchers, policy makers or curriculum developers when deciding whether to utilise the research findings in their own particular situations.

⁴ This generalisation carries the power of the counterfactual statement to a generalisation. Thus the counterfactual to "All swans are white" establishes the falseness of that statement by a single example of a black swan (Flyvbjerg, 2006).

This research is an exploratory study and did not include any intervention. However as suggested in this chapter, very important propositions have arisen from the data analysed under Wenger's framework that point towards formulation of interventions that are proactive in enabling more effective curriculum change. In particular, it could lead to teacher development programmes that take into account theories of change and learning. The psychology of how people change is often disregarded or left to chance by curriculum developers in their hurry to set into motion the new curriculum changes. However, it is proposed here that a teacher development programme that has a basic structure based on a constructivist psychology of how people learn and how people change, and then incorporates the actual curriculum change content into that structure, would stand a better chance of bringing about teacher change and curriculum change in the classrooms.

11.4 Implications for Curriculum Design

Mandated curriculum change is a complex process with an uncertain outcome (Cuban, 2001; Fensham & Corrigan, 1994). Some of the sociocultural dimensions of this complexity are illustrated in the model of the development and implementation of the New Zealand physics curriculum described in Chapter 10. From the analysis of the curriculum change process and its outcomes, three propositions are set out below. These propositions indicate possible directions for curriculum developers. However, they constitute clues rather than causes; the development and implementation of a curriculum will always be tempered by a unique socio-cultural-politico landscape (Fensham, 2002).

The first proposition is that the physics curriculum document, the key artifact, as a text, was not effective in lending itself to a 'rearrangement' of the future. Wenger (1998) suggests that in designing change, we place artifacts in place so that the future can be arranged or organised around them. He also suggests that in designed change in learning organisations, the arrangement of members of communities about the artifacts is very important. Change entails the right kind of people in the right kind of relationship to one another and to key artifacts. *Physics in the New Zealand Curriculum* was designed to bring about a rearrangement of the future, that is, a change in the school physics curriculum. However, the arrangement of the different communities of practice, such as the writers, teachers, Ministry and other

stakeholders, about this artifact, constituting their interactions and interpretations of the document within their plane of lived experiences, resulted in the outcome of the rearrangement of the future, that is, the actual change.

The outcome of design, however, must always be in doubt because, as Wenger points out, there are tradeoffs in terms of:

... rigidity versus adaptability, partiality of people versus ambiguity of artifacts, limited scope and mobility versus limited relevance and stability of interpretation. (Wenger 1998, p. 232)

The writers of the New Zealand physics curriculum deliberately chose to develop a document that was not condemnatory of current practice, yet at the same time it was hoped that the document would lead to the development of progressive physics teaching. The design choices underlying the New Zealand physics curriculum document allowed much of current practice to continue to occur. Thus teacher pedagogical commitments, ranging from a recommitment to traditional teaching to a commitment to adopt new kinds of practice, could all be accommodated. If there had been greater specification in the reified curriculum, the outcome may have been different. Fensham and Corrigan (1994) describe how in Victoria, Australia, the more prescriptive 'work requirements' of the VCE chemistry curriculum moved teachers to modify their practices. However, even with greater specification there was still a wide range of teacher commitments to the curriculum. As Wenger comments:

... practice is (among other things) a *response* to design. Unexpected adaptations of the design are inherent in the process. They do not necessarily indicate a lack of specification. In fact they may very well indicate a healthy response ... (p. 233)

A second proposition is that a major constraint on teacher commitment to the physics curriculum change was the lack of transparency in curriculum development. A curriculum document, as with any object, when viewed from outside of its reifying community of practice, can be seen to be a "Black Box"⁵. In Wenger's analysis, if the curriculum is an artifact which has the appearance of a "Black Box" then its use by

⁵ The term "Black Box" is one often used in systems theory for a process in which the functions linking input and output have not been identified (although they may be described). Lave and Wenger (1991) used the concept of a black box.

community members is likely to be only procedural. The engagement of the community with the artifact may be limited in meaning:⁶

Procedures can hide broader meanings in blind sequences of operations. And the knowledge of a formula can lead to the illusion that one fully understands the processes it describes. (Wenger, 1998, p. 61)

With only a procedural understanding of an artifact, members of a community of practice cannot easily engage in negotiation of meaning as their application of the artifact is automatic; they have limited imagination beyond their own practices, and their ability to align their contributions to the wider network is curtailed. Lave and Wenger (1991) suggest that it is possible to ensure that rather than a "Black Box" there can be a transparent "Glass Box". They suggest that there is a relationship between transparency leading to full access to cultural artifacts and full participation in a community of practice.

For those involved with the New Zealand physics curriculum, such a "Glass Box" did not arise as there was not the development of boundary conditions allowing transparent discourse between curriculum writers, teachers, stakeholders, and Ministry of Education policy makers (who specified the terms of the curriculum writing contract). The possibility of such a discourse between these parties in turn would have entailed the existence of boundary objects (such as shared commentaries from the various communities on the deeper rationale of the curriculum document) and brokers between different communities of practice. The writers, being teachers themselves, could in principle have participated in the setting up of such a dialogue between the teachers' community of practice and those of other stakeholders. However, as discussed in Chapter 10, the tight time cycle of the curriculum development could not accommodate such a dialogue.

The third proposition is that lack of support for teachers in their dereification of the physics curriculum document impacted negatively upon curriculum change. Teachers as a community of practice develop shared meanings during their dereification of a new curriculum. However, to do so most effectively (from the curriculum developer's point of view) entails the development of boundary objects to mediate understandings

⁶ In fact, Wenger does suggest a nexus between the development of practice and experience. That is, there is the possibility that if procedural knowledge allows engagement, then a development of a more reflective knowledge may occur.

between different communities of practice. An example of such a document would be a teachers' guide explicating the history, philosophy, and best practices of the new curriculum (the absence of which was noted by the writers). Such a support would empower those involved in teacher development to take on more of a role of "broker" between the views of different communities of practice who have influenced the curriculum development. As such, their focus would be not just the "what" of the new curriculum, but the negotiation of the meaning of the changes heralded in the curriculum document. Under such conditions the meanings of the curriculum writers, contained in the reified curriculum, might have unfolded more fully in practice and impacted on the beliefs held by physics teachers (see Wenger 1998).

The above three propositions are related to the three key elements for teacher change which are in-depth knowledge of the change (includes the *what*, *how* and *why* of the proposed change), support and time needed for effective teacher change. These key elements are mentioned in the research findings (see section 11.2) and were developed in Chapter 9.

For the implementation of *Physics in the New Zealand Curriculum*, the conditions outlined above were absent. In the view of the New Zealand Ministry of Education, when the physics curriculum document was completed so was the curriculum writers' task ⁷. The lack of sufficient funding meant that the writing of a Teachers' Guide to accompany the document was curtailed. Thus the attempt at change was under-resourced, with insufficient professional development to accompany the curriculum document. This was "change on the cheap" (Andy), but for the Ministry of Education, the surface appearance of there being a radical change was more important than the actual depth of change: ⁸

For the system bureaucrat, the beginning of implementation marks the end of the change initiative. The teacher has to live with the consequences. (Gunstone, 2002)

⁷ The original proposal included the writing of a curriculum guidebook, but ultimately no funding was allocated to that.

⁸ In contrast from Wenger's sociocultural perspective: 'A curriculum then would look more like an itinerary of transformative experiences of participation than a list of subject matter' (Wenger 1998, p. 272).

While arrangement around the artifact; lack of transparency; lack of support to dereify, lack of professional and structural support, and time, all contributed to a lack of profound change in practice, the lack of change can also be seen as stemming from the very nexus of the politics of curriculum. Certainly in the New Zealand physics curriculum reform, the impetus behind developing the new curriculum was political as well as educational. Under the New Zealand National Party government of the time, mandated curriculum reforms were made across all subjects. The general thrust of these reforms was towards enhancing a meritocracy based upon developing a more standards based curriculum that linked in with a qualifications framework based around standard assessment tasks. The National Curriculum was heralded under the modernist slogan of it being a curriculum to take New Zealand into the 21st century. Such a slogan, if anything, added to the power and influence of key interest group drivers including academic scientists, business and education bureaucrats. Not surprisingly, as with many science curriculum change examples (Aikenhead, 2002; Blades, 1997; Fensham & Corrigan, 1994), the final state of the curriculum reflected the power of these groups to define the discourse:

There was hell of a lot of outside influence on the construction of this thing. ... I think that the process of creating this curriculum was wrong. ... If I was asked to design a curriculum again, I don't know if I would agree to do it if someone tried to give me the same sort of terms of reference to do it under. (Writer 3)

Further analysis of the development and implementation of *Physics in the New Zealand Curriculum* utilising post-modern and critical theory frameworks would yield additional insights into the political dimensions of the physics curriculum change.

11.3 Conclusion

This thesis has provided a sociocultural account of how a change of practice, reified in a curriculum document, proceeded. It has drawn heavily on the theoretical work of Wenger (1998) that illuminates the dynamic between artifact and participation in a community of practice as integral to the process of change. A very significant issue in this dynamic situation is that if a reification of a design for practice is merely presented to a community of practice without intersubjective linkage with its

designers, then during 'dereification'⁹ both the extent and form of any change in practice will be compromised. It is the presence (or absence) of significant participation between teachers and the other communities of practice including curriculum writers, scientists, business stakeholders and bureaucrats, which influences the dereification of the reified curriculum document. I have argued that it is the teachers' dereification of the curriculum document that is critical to the ultimate direction of changes in practice.

There are a number of education system factors that contribute to shifts in the practices in an educational community. This analysis has indicated several significant factors that worked against real change occurring in the particular case of the new New Zealand physics curriculum. The ambivalence within the curriculum document regarding the possible arrangement of teachers about the curriculum, the lack of transparency of curriculum development, the lack of support for teachers dereifying the curriculum document, all acted as impediments towards major change occurring.

The three key elements identified in Chapter 9, knowledge, support and time, for effective change can be superposed onto relevant sections of the model of curriculum change cycle of reification and dereification developed in Chapter 10 (Figure 8). It would be valuable for the initiators of curriculum change to design interventions that give opportunities for appropriate knowledge, support and time to be made available to teachers at critical points in the curriculum change cycle. Support for curriculum change based upon these factors would provide teachers with the resources they need for pedagogical change to occur. In the case of *Physics in the New Zealand Curriculum*, the curriculum writers were brokers at the boundaries of the teachers' community of practice and the other stakeholder communities involved in the curriculum change. If the Ministry of Education had wanted it, the writers could have designed teachers' guides and professional development opportunities to provide physics teachers with knowledge of the curriculum rationale and support teachers through the change. Unfortunately, the Ministry of Education did not consider the job of curriculum development for a new school physics curriculum to extend much past the production of the physical document. Heed was not paid to the warning made

⁹ At dereification, a designed artifact is taken up and used in practice.

many years ago by C. E. Beeby, the New Zealand Director of Education for the period 1939 to 1960:

...unless the individual classroom teacher both understands and personally accepts the qualitative changes that are being planned, no significant change will occur in her/his practice. (Beeby, 1974, p. 157)

Education bureaucrats and curriculum developers need to be constantly reminded of the uncertain outcomes of curriculum development provided by examples such as the case of the New Zealand physics curriculum change for secondary schools presented in this thesis. Such examples highlight issues that have significant impact on the participation and meaning-making of teachers involved in curriculum change. If they ignore such issues, curriculum developers will find themselves marginalised, and the cultural objects they have developed being adapted in unintended ways from the drawing board into schools.

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APPENDICES

APPENDIX A: Pages from *Physics in the New Zealand Curriculum* (Ministry of Education, 1994).

APPENDIX B: Sample letter for teachers' informed consent

APPENDIX C: Schedules of Interview Questions

APPENDIX D: Brief Summary by Researcher of the Writing Contracts

APPENDIX A: Pages from Physics in the New Zealand Curriculum

Pages reproduced from *Physics in the New Zealand Curriculum* (Ministry of Education, 1994) including:

- A1** Levels 6-8 (pp. 16-40)
- A2** Physics Achievement Aims (p.14)
- A3** Developing Investigative Skills and Attitudes in Physics (pp. 42-43)
- A4** Possible Learning Experiences related to Investigative Skills (pp. 44-47)
- A5** Purpose of Physics Education (p. 6)
- A6** Approaches to Teaching and Learning in Physics (p.7)
- A7** Development of the Essential Skills (pp. 8-9)

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FOREWORD

This curriculum statement provides the basis for the development of teaching programmes in physics in the senior secondary school. By relating physics principles and the development of skills to the contexts in which they are used, both in the classroom and in the wider world, school physics programmes will provide learning which the students can see to be relevant, meaningful, and useful to them. The achievement aims and objectives will also be used by the New Zealand Qualifications Authority for the development of Unit Standards and new examination prescriptions. Full implementation of the new curriculum in physics will take place from 1997.

Physics in the New Zealand Curriculum is designed to meet the needs of all students who choose to study physics in the senior secondary school. Included in this group will be students requiring a background in physics for further study. Many of these students will begin this specialised study at curriculum level 7. For this reason, the assumed background of students seeking to achieve level 7 objectives is achievement of level 6 objectives in *Science in the New Zealand Curriculum*. The inclusion of level 6 objectives in this statement provides schools with the option of offering three years of specialised study in physics.

I am grateful to all who have contributed to the development of this curriculum statement, especially the contractor and writers, the reference group members, the Minister's policy advisory group, the review committee, and Ministry staff, all of whom contributed their expertise and experience.

Maris O'Rourke

Dr Maris O'Rourke
Secretary for Education

INTRODUCTION

Physics is the branch of science in which people explore the physical world around them and seek to understand and describe the phenomena they encounter. Learning in physics is inspired by a simple wonder at the way things are and a compelling curiosity about why they work the way they do. A study of physics spans the limits of our universe — from the subatomic to the size of galaxies — and develops skills and knowledge that are useful in today's world and important in further learning.

Learning physics involves students investigating physical phenomena and developing concepts, principles, and models in explaining those phenomena. As students develop scientific knowledge and skills, they are given an opportunity to become aware of their own intellectual and vocational potential and to develop further the essential skills, such as problem solving, numeracy, and communication, described in *The New Zealand Curriculum Framework*.¹

Increasingly, our lives have become dependent on science and technology. A knowledge of physical processes and their applications allows students to make their own well-reasoned decisions on issues related to science, technology, and society.

This curriculum promotes a creative, relevant, and people-oriented image of physics. It is designed to encourage students of any age, gender, and cultural background to take an active interest in the physical world, and to use learning opportunities to make sense of it.

This statement on physics should be read in conjunction with the more general statement on science in *Science in the New Zealand Curriculum*.²

Physics Education³

The purpose of physics education is to develop people who:

- are effective, independent, enthusiastic learners, and good communicators;
- have a good operational understanding of basic concepts, principles, and models of physics;
- are skilled practical investigators and problem solvers who enjoy working at the boundaries of their own understanding;
- understand the nature of scientific knowledge and the relationships between science, technology, and society;
- are able to work effectively and co-operatively with others;
- maintain scientific integrity in their pursuit of physical knowledge.

¹ MINISTRY OF EDUCATION, *The New Zealand Curriculum Framework: Te Anga Māhanga o Aotearoa*. Wellington: Learning Media, 1993.

² MINISTRY OF EDUCATION, *Science in the New Zealand Curriculum*. Wellington: Learning Media, 1993.

³ Adopted in 1993 as policy by the New Zealand Institute of Physics.

APPROACHES TO TEACHING AND LEARNING IN PHYSICS

This statement should be read in conjunction with the sections Enhancing Achievement and Science for All in *Science in the New Zealand Curriculum* which acknowledge that:

Quality science education for all students requires the removal of barriers to achievement and encourages continuing participation in science. Accordingly, the curriculum in science should recognise, respect, and respond to the educational needs, experiences, achievements, and perspectives of all students: both female and male; of all races and ethnic groups; and of differing abilities and disabilities.

An inclusive curriculum that recognises the perspectives of a particular group of students can enrich education in science for all students. (page 11)

Teaching and learning involve a partnership between students and teacher where all are actively engaged in the learning process. Learning in physics is enhanced when:

- teaching programmes acknowledge that students bring to the classroom a host of personal experiences, ideas, concepts, and attitudes about the physical world;
- teaching approaches recognise students' existing experiences and build on them;
- students investigate real situations of interest to them;
- learning contexts, learning experiences, and teaching approaches are accessible, interesting, and appropriate to students;
- teaching approaches consider the language of physics, both the specialist technical terms and the everyday words that also have special meaning;
- students are encouraged to take responsibility for their learning and to engage in thinking about and linking the facts, ideas, and phenomena they encounter;
- teachers adopt a range of roles and provide a range of learning opportunities and assessment activities;
- sufficient resources such as materials, equipment, laboratory space, and technical support are provided;
- students get the chance to investigate and apply ideas both in idealised contexts and in a variety of realistic contexts;
- students develop, share, re-shape, and consolidate their conceptual understanding through contexts involving natural phenomena, technological devices, mechanisms, and systems;
- teaching programmes form links with local physics-related enterprises;⁴
- students are given the opportunity to develop their understanding of interactions between physics, technology, and society and to increase their awareness of the evolving nature of physics;
- people in physics-related occupations become role models by contributing to physics programmes as visiting speakers or as consultants' investigations.

Use of the above approaches to teaching and learning will enable students to develop knowledge, skills, and attitudes in physics thoroughly, equitably, and with affection and enjoyment.

⁴Readers are invited to refer to the Ministry of Education publication, *Working Together*, Wellington, Learning Media, 1993.

DEVELOPMENT OF THE ESSENTIAL SKILLS

In planning physics programmes, teachers need to ensure that all students have the opportunity to develop the full range of essential skills outlined in *The New Zealand Curriculum Framework* (pages 17-20). Learning in physics provides opportunities for the development of these skills.

- **Communication skills**
Students will continue to develop confidence and competence in communicating their ideas. They will use a variety of means of communication including modern information and communications technologies. They will also develop skills of discrimination and critical analysis in relation to the variety of sources of information they use.
- **Numeracy skills**
The development of numeracy skills is especially important in physics. Students will:
 - calculate accurately;
 - estimate proficiently and with confidence;
 - use calculators and a range of measuring instruments confidently and competently;
 - understand, analyse, and present information in graphs, tables, etc;
 - recognise and use numerical patterns and relationships.
- **Information Skills**
As students will use information from a range of sources in physics, information skills are of special importance. Physics activities provide students with opportunities to develop essential information skills:
 - identifying, locating, gathering, retrieving, and processing information;
 - organising, analysing, synthesising, and evaluating information;
 - presenting information clearly, logically, concisely, and accurately.
- **Problem-solving skills**
The physics curriculum offers rich contexts for problem solving such as:
 - identifying, describing, and refining a problem;
 - making connections and establishing relationships;
 - inquiring and researching, and exploring, generating, and developing ideas;
 - generating and testing hypotheses, and making decisions on the basis of experience and supporting evidence;
 - evaluating processes and outcomes.
- **Self-management and competitive skills**
Students engaged in physics will need to set and achieve goals; manage time and other resources effectively; and show initiative, perseverance, and commitment. They will also develop the skills of self-appraisal and take increasing responsibility for their own health and safety.

- Social and co-operative skills

Learning activities in physics provide opportunities for students to relate to others and work co-operatively and collaboratively.

- Physical skills

Students will have opportunities in physics to develop manipulative skills and learn to use tools, equipment, and materials effectively, efficiently, and safely.

- Work and study skills

Activities in physics can involve students working independently, in groups and with people, including scientists from the wider community. These activities should encourage students to take increased responsibility for their own learning and work, and develop the desire and skills to continue learning through life.

THE LANGUAGE OF PHYSICS

Physicists use particular words and phrases in a special sense to convey information and meaning. Thus it is important that teaching approaches consider the language of physics, both the specialist technical terms and phrases and the everyday words that also have special meaning.

Moreover, language is integral to learning concepts and principles, so opportunities for student explanations, discussions, presentations, and writing in both technical and non-technical language should occur. Teaching approaches should consider how a balance of verbal and mathematical language best promotes learning in physics.

THE PLACE OF MATHEMATICS IN PHYSICS

Mathematics is intrinsic and indispensable in physics. Particular methods of mathematical analysis, such as calculus, have been invented while attempting to analyse and explain physical phenomena. This has resulted in the description of physical concepts and principles in succinct mathematical forms.

Mathematics permeates all aspects of physics, from measurement and analysis of data in an experiment, to algebraic manipulation of equations in the development of theories.

Consequently, students are expected to develop skills and understanding of relevant mathematical processes in their study of physics. Their competence in mathematics is expected to go beyond just skills in numeracy.

Mathematical processes of importance in physics at levels 6, 7 and 8 include:

- basic numerical operations, manipulation of algebraic expressions, substitution of numerical values into expressions, and use of scientific notation;
- manipulation and analysis of vector quantities;

- familiarity with functions commonly encountered in physics, e.g., linear, quadratic, inverse, inverse square, sinusoidal, exponential;
- use of proportion when exploring relationships between variables;
- analysis and manipulation of units associated with physical quantities;
- estimation of quantities using orders of magnitude;
- use of uncertainty estimations and significant figures in determining the precision of measured and calculated quantities;
- use of the mean of samples of data;
- graphical treatment of data in determining relationships.

For able students teachers could include the mathematical processes of elementary calculus, e.g., rates of change, and further statistical methods for analysing data.

Students are expected to develop increasing competence in their use of mathematical processes as they continue their learning in physics. In general it is expected that students will be able to use mathematical knowledge and skills specified in prior levels of the mathematics curriculum.

SAFETY

The Health and Safety in Employment Act 1992 concerns itself with management systems to ensure the health and safety of employees and other people in places of work, which includes schools. It is important that school boards of trustees ensure teachers, technicians, and students maintain safe practices in a physics laboratory, especially concerning:

- behaviour and movement in and around the laboratory;
- storage and handling of equipment and materials, especially electrical equipment and radioactive samples;
- the provision of and ease of access to first aid equipment and fire extinguishers.

Before participating in physics activities, especially demonstrations and practical investigations, teachers and students should be familiar with relevant sections of the *Ministry of Education Health and Safety Code of Practice for State Primary, Composite, and Secondary Schools* (Learning Media, Wellington, 1993), which prescribes physical standards of health and safety appropriate to schools.

FORMAT OF THE PHYSICS CURRICULUM

Achievement Aims

The achievement aims encapsulate what is considered important in teaching and learning physics. It is expected that in a coherently organised teaching programme, the achievement aims will be integrated in such a way that each contributes to and reinforces the development of the others.

Achievement Objectives

The achievement objectives at each level are derived from the achievement aims. These objectives interpret the aims in more specific terms that can be demonstrated.

Sample Learning Contexts

The sample learning contexts are examples of familiar and/or interesting settings which should help students to develop their understanding. Contexts could be used as a starting point for a topic, or as a theme which may link several achievement objectives. Although each context is presented at a particular level, some could be used at other levels. The sample learning contexts are suggestions only, and teachers are encouraged to choose their own, especially when this involves local examples and resources.

Possible Learning Experiences

Students should participate in a wide variety of learning experiences to ensure they have opportunities to develop the knowledge, skills, and attitudes described by the achievement objectives. A range of possible learning experiences is given at each level. In many cases a possible learning experience contributes to more than one achievement objective.

The possible learning experiences are suggestions and not intended to be compulsory. Teachers are encouraged to incorporate some of them into their programmes, and to include other suitable learning experiences to ensure that complete and balanced programmes are achieved.

When the possible learning experiences at any one level are considered collectively, they give guidance about concepts, language, approaches, techniques, materials, and equipment appropriate to the level. They also suggest the scope and depth of the expected learning, and show the progression in learning from one level to another.

The choice of possible learning experiences will depend on a number of important variables. These include the nature of the targeted achievement objectives, the composition of a particular class, the community of which the school is a part, the interests of students and teachers, topical events, and time of the year.

Assessment Examples

The assessment examples provide guidance for planning suitable assessment tasks which should be an integral part of the learning programme. They also show how the assessment of knowledge, skills, and attitudes is interrelated, including the essential skills identified in *The New Zealand Curriculum Framework*.

As with the sample learning contexts and possible learning experiences, the assessment examples indicate the nature and range of suitable assessment opportunities. Teachers will also need to locate and devise other assessment activities.

In planning programmes, teachers should be sensitive to the different learning and communication styles of their students. Therefore, a variety of assessment approaches should be used to measure the range of knowledge, skills, and attitudes expected to be developed at each achievement level.

Teachers should also refer to the Ministry of Education handbook, *Assessment: Policy to Practice* (Learning Media, Wellington, 1994) for advice on assessment.

PHYSICS PROGRAMMES

The achievement aims and objectives are not listed in an order of priority nor should they be interpreted as requiring equal amounts of time to be spent on each one. The amount of time students spend on each aim and objective will be determined by their prior knowledge and skills in relation to each objective in their programme.

In planning programmes, teachers are encouraged to link achievement objectives derived from different aims to provide integrated learning experiences, and teachers are expected to develop and use specific learning outcomes derived from the achievement objectives. These outcomes should be placed within contexts that are appropriate to the learning needs of their students. These specific learning outcomes provide the criteria against which a student's achievement can be assessed by teachers and students, using a variety of assessment procedures. This information can be used to make judgments about a student's achievement in relation to the achievement objectives.

Aim two concerning the nature of physics and its impact on society is expected to be integrated with the teaching of the core content and to account for less course time than either of the other two aims. Investigative work is expected to be similarly integrated and to take a significant amount of course time.

Some schools may wish to extend coverage of the content by including some of the optional material suggested in the curriculum. Others may elect to provide background knowledge for students picking up physics at a particular level.

PHYSICS ACHIEVEMENT AIMS

In their study of physics, students will use their developing scientific knowledge, skills, and attitudes to achieve the following aims.

1. Students will develop:
 - (a) an understanding of concepts, principles, and models in physics;
 - (b) the ability to use concepts, principles, and models to explain physical phenomena, systems and devices;
2. Students will appreciate:
 - (a) the nature of theories and models in physics;
 - (b) how physics and physics-based applications impact on society and are influenced by the needs and attitudes of people;
3. Students will develop practical investigative skills and attitudes to:
 - (a) determine relationships, patterns, and trends in physical phenomena, systems, and devices;
 - (b) identify and explain applications of concepts and principles in physics.

The order of the aims above does not indicate their relative importance.

Students should also appreciate the interwoven nature of these aims, and that all three aims should be seen as essential aspects of effective learning in physics and in developing their physics vocabulary.

The investigative skills and attitudes students are expected to develop have been described as achievement objectives in *Science in the New Zealand Curriculum*. The final section of this statement includes these achievement objectives and suggests possible learning experiences appropriate to physics.

PHYSICS: LEVEL 6 Form 5 Yr 11

Achievement Objectives

In the content areas listed below students can:

- 6.1 (a) demonstrate an understanding of concepts, principles, and models, e.g., Newton's Laws, conceptual models for electric current;
(b) apply concepts and principles to explain physical phenomena, systems, and devices, e.g., loudspeakers, hairdryers;
- 6.2 (a) explore the use of experimental evidence in developing theories and models, e.g., number of measurements needed to determine a relationship, reliability of data;
(b) describe influences of everyday physics-based applications on their lives, e.g., spectacles, light bulbs, the combustion engine;
- 6.3 (a) carry out practical investigations* to determine relationships, patterns, and trends in physical systems, e.g., frictional forces and type of surface, graphing temperature changes;
(b) carry out practical investigations* to explore applications of physical concepts and principles, e.g., the optical system of an overhead projector.

*The achievement objectives for investigative skills at level 6 are outlined on pages 42 and 43.

CONTENT	SUGGESTED OPTIONAL CONTENT
Mechanics Displacement, velocity, acceleration, and graphical representation of motion in one dimension; Newton's First and Second Laws and ideas of resultant forces and equilibrium of forces; Frictional forces and free body force diagrams; Mass, weight, and the acceleration due to gravity; Pressure and density; Work and power, gravitational potential energy, kinetic energy, and the conservation of mechanical energy;	Structures, stability, and centre of gravity; Simple machines (levers, gears, pulleys, inclined planes) and their efficiency; Flotation and Archimedes' Principle;

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CONTENT	SUGGESTED OPTIONAL CONTENT
Electricity Idea of positive and negative charge, electrostatic forces, conductors and insulators; Conceptual model for the behaviour of simple circuits using ideas of current, voltage, resistance, and series and parallel connection of resistors; Graphical representation of the relationship between current and voltage in ohmic conductors; Energy dissipation and power in resistors;	Domestic electrical circuits; Use of switches and diodes in circuits;
Electromagnetism Magnetic fields due to current in wires and solenoids; Magnetic force on a current carrying wire; The simple DC motor;	Loudspeakers;
Heat Heat and temperature; Conduction, convection, and radiation of heat;	Heat capacity and latent heat; Linear expansion;
Light and Waves Convex and concave lenses, and their applications; Longitudinal and transverse waves, period, wavelength, frequency, amplitude, speed, and their relationships;	Colour; Ultrasound and microwaves;
Atomic and Nuclear Physics Atomic no., mass no., isotopes, nuclear fission, and nuclear reactors.	

Sample Learning Contexts

The physics of toys • Loudspeakers and microphones • Transport
Physics and leisure • Eye defects • Robotics • The motor car • Musical instruments
Vision systems • Audiology • Telescopes • Fibre optics • Forensic science
Photography • Light dimmers • Cycling • Local industry • Science fairs
Physics in sports

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Possible Learning Experiences

The following are examples of learning experiences teachers could choose to provide, depending on the resources available. These examples are suggestions only and are not intended to be prescriptive. A range, from tightly defined tasks to broad investigations, has been included. Even though these learning experiences are grouped under headings, a range of learning outcomes is possible from each learning experience.

Achievement Objective 6.1(a)

Students *could* be learning by:

- using simple electrical circuits to demonstrate the working of electrical components, e.g., resistors, batteries, rheostats, diodes;
- using a signal generator, loudspeaker, microphone, and oscilloscope to establish ideas of frequency, pitch, amplitude, and loudness of sound waves;
- discussing how the idea of heat of vaporisation applies in conserving body heat and avoiding hypothermia while tramping;
- discussing personal experiences of forces by considering questions such as: "Why is it easier to slip on ice than on a gravel path?";
- viewing a children's cartoon and making a list of physical events that are inconsistent with reality.

Achievement Objective 6.1(b)

Students *could* be learning by:

- studying the passage of sound through different media and relating this to its use in ultrasound scanning of the body and in determining pregnancy in sheep;
- using measurements of the lifting rate of model cranes in introducing the concepts of work and power;
- discussing how an electric fence delivers a shock to a farm animal;
- considering how the concept of acceleration and graphs of motion can lead to determining safe stopping distances while driving;
- identifying physical concepts and principles incorporated in the design of a selection of children's toys;
- designing, on paper, a plan for a domestic hot-water system based on scientific principles;
- dismantling a simple device based on physical principles studied (e.g., a pair of binoculars) and presenting ideas on how it works to the class;
- using the concept of latent heat in describing the operation of a refrigerator;

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- corresponding with or visiting a local manufacturer or service agent to find out the physical principles involved in devices of interest to students, e.g., tape recorder, camera, hairdryer, milking machine, hay-baler;
- using the concept of force on a current-carrying conductor in describing the operation of a loudspeaker, electric motor, or ammeter;
- using the concept of electrostatic attraction to explain the main idea in the design of a photocopier.

Achievement Objective 6.2(a)

Students *could* be learning by:

- repeating an experiment to test explanations for why initial experimental results did not match predictions;
- examining the reliability of interpolating and extrapolating experimental data;
- discussing the question: "Are there such things as wrong results?";
- discussing whether or not data collected is sufficient to allow a conclusion to be made regarding the aim of an investigation, e.g., taking into account limitations of equipment, variability of data, number of measurements;
- considering the possible conflict between the results of experiments and the students' intuitive ideas, e.g., deciding whether an object needs to have a resultant force acting on it for it to continue in motion.

Achievement Objective 6.2(b)

Students *could* be learning by:

- reading about the work of physicists (such as Marie Curie or Michael Faraday) and preparing a short newspaper article about the influence of their work on the students' lives;
- listing the advantages or disadvantages of a "sonic fence" used to protect people from stray dogs;
- discussing the advantages of using a thermal blanket for treating hypothermia cases;
- carrying out a survey to find out the number of electric motors used in one day by each student;
- examining the impact of optical systems, e.g., spectacles, on peoples' lives;
- keeping a class journal or scrapbook on current world events or recent developments in physics from which students can report to the class;
- considering how combinations of lights and mirrors can be used in shops to artificially enhance the appearance of goods.

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Assessment Examples

The following assessment activities are examples of tasks which teachers could devise to provide diagnostic, formative, or summative information in their own assessment programme. A small selection of aspects which teachers might choose to assess is provided for each of the example activities.

Achievement Objective 6.1(a)

- Students design their own simple motion problems and write their own solutions.

Using this example, teachers and students could assess the students' ability to:

- choose simple situations and realistic data;
- use data and graphs of motion to calculate an appropriate solution;
- evaluate the suitability of other students' problems.

- Students draw a diagram of the magnetic field pattern around two parallel bar magnets fixed a small distance apart.

Using this example, teachers and students could assess the students' ability to:

- make idealisations from an imperfect iron-filings pattern;
- recognise that magnetic field lines do not intersect and are directed from north to south;
- draw a clear diagram with appropriate labels;
- apply physical principles to a new situation.

Achievement Objective 6.1(b)

- Students consider how astronauts could communicate with each other on the Moon.

Using this example, teachers and students could assess the students' ability to:

- apply relevant physical principles such as the need of a medium for sound to travel;
- access scientific information appropriate to their own level of understanding.

- Students design a poster displaying the structure of the eye and ray diagrams which show how lenses correct for long-sighted and short-sighted eyes.

Using this example, teachers and students could assess the students' ability to:

- accurately draw ray diagrams in relation to each eye's structure;
- access scientific information appropriate to their own level of understanding;
- organise information concisely;
- display information.

Achievement Objective 6.3(a)

Students could be learning by:

- using a simple device of their own design to show how pressure in a liquid varies with depth, and plotting a graph of the relationship;
- establishing the relationship between applied force and extension for a given elastic material, and using this knowledge to devise a method to measure the weight of particular objects;
- graphing temperature changes measured in different parts of the school on different days to establish trends;
- using a variety of instruments for measuring time and distance (from stop-watches and rulers to electronic devices and computers) in order to plot, interpret, and explain the motion involved in some simple situations such as people running, people cycling, balls rolling down ramps;
- carrying out a practical investigation selected from a list of topics (which could take up to two weeks of class time), keeping a log book, and completing a full report;
- investigating the relationship between stopping distance and initial velocity for a trolley coasting to a halt on a piece of carpet;
- devising an investigation to compare the insulation properties of various materials;
- calculating the cost of heating a 50 000 litre swimming pool by 10° C, using laboratory measurements made when heating water.

Achievement Objective 6.3(b)

Students could be learning by:

- carrying out an investigation into the factors that enhance the drying of washing on a clothes line;
- calculating the cost of electrical energy used in the students' households by reading the meter at the beginning and end of a twenty-four hour period;
- comparing the advantages and disadvantages of using analogue and digital meters;
- assisting the teacher in planning a learning programme to explore applications of physics in the home;
- designing an electrical circuit to provide lighting in a model house;
- determining the focal lengths of various spectacle lenses;
- investigating how various cultures make ropes, and determining relative strengths related to rope thickness.

Achievement Objective 6.2(a)

- Students investigate whether a hot drink left for ten minutes cools to a lower temperature if milk is added at the start or at the end of the ten minutes.

Using this example, teachers and students could assess the students' ability to:

- justify scientifically the prediction they make;
- appreciate which variables need to be kept constant;
- recognise that data collected may be insufficient to make a confident conclusion.
- Students consider evidence to date of the effects on humans of low frequency magnetic fields from computer monitors.

Using this example, teachers and students could assess the students' ability to:

- accept the provisional nature of a scientific explanation derived from limited data;
- consider the worth of competing explanations and conflicting patterns of data.

Achievement Objective 6.2(b)

- Students prepare a school newspaper article about a family's reaction to the introduction of a physics-based appliance (e.g., a microwave oven) into their home.

Using this example, teachers and students could assess the students' ability to:

- plan appropriate questions to ask;
- keep a record of the desired information;
- effectively communicate findings.
- Students categorise applications in their home or school that use the phenomenon of pressure.

Using this example, teachers and students could assess the students' ability to:

- identify the use of pressure in a range of applications;
- categorise applications as "essential", "desirable", and "undesirable" and defend their choices.

Achievement Objective 6.3(a)

- Students design and carry out an investigation to measure the focal length of a lens.

Using this example, teachers and students could assess the students' ability to:

- provide a written plan of an investigation;
- set up equipment for the collection of data;
- collect appropriate data;
- use the data to calculate the focal length.

- Students carry out an extended practical investigation of their choice which could take up to three weeks of class time. Students keep a log book and complete a full report as well as giving a presentation to the class on their work.

Using this example, teachers and students could assess the students' ability to:

- work and learn independently;
- keep appropriate records of their work;
- set goals, organise their time, and meet deadlines;
- co-operate with others in the sharing of resources.

Achievement Objective 6.3(b)

- In groups, students design an application based around heat conduction and devise a suitable test to judge its effectiveness.

Using this example, teachers and students could assess the students' ability to:

- contribute towards achieving a group goal;
- assess the performance of a technological device.
- Students measure the heat capacities of various types of kōhatu (hangi stones).

Using this example, teachers and students could assess the students' ability to:

- record and present data;
- recognise factors other than heat capacity that influence the suitability of a particular stone;
- make a decision about the most suitable type of stone;
- use equipment and materials safely.

PHYSICS: LEVEL 7

Form 6 Yr 12

Achievement Objectives

In the content areas listed below students can:

- 7.1 (a) demonstrate an understanding of concepts, principles, and models, *e.g.*, *conservation of momentum, centripetal force*;
- (b) apply concepts and principles to explain physical phenomena, systems, and devices, *e.g.*, *fibre optics, bicycle dynamos*;
- 7.2 (a) describe how physical theories and models have developed, *e.g.*, *the development of increasingly sophisticated atomic models*;
- (b) explain how developments in physics-based applications can lead to changes in society, *e.g.*, *the effect of the electric motor on home life, the effect of the combustion engine on the mobility of people*;
- 7.3 (a) carry out practical investigations* to determine relationships, patterns, and trends in physical systems, *e.g.*, *light intensity changes, measuring "g"*;
- (b) carry out practical investigations* to identify and describe applications of physical concepts and principles, *e.g.*, *thermostats, volume controls*.

*The achievement objectives for investigative skills at level 7 are outlined on pages 42 and 43.

CONTENT	SUGGESTED OPTIONAL CONTENT
Electricity Quantitative analysis of currents, voltages, and power dissipation in series/parallel circuits using Ohm's Law; Voltage dividers; Properties of non-ohmic conductors such as light emitting diodes, light dependent resistors, thermistors;	<i>Internal resistance and resistivity;</i> <i>Use of components in electronic circuits, including transistors, relays, etc;</i>
Electromagnetism Quantitative treatment of the magnetic force on a current carrying conductor; Force on a charged particle moving in a magnetic field; Induced voltage generated across a straight conductor moving in a uniform magnetic field, simple generators;	<i>Magnetic force between two parallel wires carrying current, the definition of the ampere;</i> <i>Comparison of methods of electricity generation (hydroelectric, geothermal, thermal, tidal, solar, nuclear);</i>
Light and Waves Reflection and refraction of light and water waves; Superposition of waves; The electromagnetic spectrum;	<i>Optical instruments (microscopes and telescopes, etc);</i>
Atomic and Nuclear Physics Atomic models; Radioactive decay, half life and alpha, beta, and gamma emissions.	<i>Industrial and medical applications of nuclear physics.</i>

Sample Learning Contexts

Camera lenses • Lasers • The mechanics of the human body • Telecommunications
Making electronic circuits • X-rays • Science award schemes • Computers • Medicine
Helping people with disabilities • Kitchen technology • Paying for electrical power
Safety in the home • Water waves

CONTENT	SUGGESTED OPTIONAL CONTENT
Mechanics Kinematics equations for translational motion in one dimension; Relative motion, including the addition and subtraction of vectors; Components of vectors, projectile motion, and circular motion;	<i>Terminal velocity;</i>
Lever, torque, and the principle of moments; Momentum and its conservation, impulse, and Newton's Third Law of Motion; Energy changes in elastic and inelastic collisions, Hooke's Law and elastic potential energy;	<i>Pressure in fluids, fluid flow and Bernoulli's Principle;</i> <i>Newton's Second Law in terms of rate of change of momentum;</i>

Possible Learning Experiences

The following are examples of learning experiences teachers could choose to provide, depending on the resources available. These examples are suggestions only and are not intended to be prescriptive. A range, from tightly defined tasks to broad investigations, has been included. Even though these learning experiences are grouped under headings, a range of learning outcomes is possible from each learning experience.

Achievement Objective 7.1(a)

Students *could* be learning by:

- estimating the amount of work done when a car accelerates from rest to 50 km h^{-1} ;
- discussing the forces acting at significant points along the path of a ball thrown vertically in the air;
- exploring, in groups, the meaning of a particular word in many contexts and coming to a class decision on its meaning in physics, e.g., work, cell, potential, wave;
- observing and investigating the behaviour of colliding trolleys in order to develop an understanding of momentum conservation;
- discussing whether a passenger in a car is being forced towards or away from the centre when the car moves around in a circle;
- watching a video on ocean waves and demonstrating the properties of these waves, using a ripple tank.

Achievement Objective 7.1(b)

Students *could* be learning by:

- finding out how the domestic electrical system works;
- cutting open the flasher unit from a vehicle indicator system and watching and explaining how it operates;
- observing internal reflection of a light beam inside a stream of water and relating this to its applications in fibre-optic cables;
- making a model of an angle-poise lamp to show the different orders of levers used in its action;
- examining the movement of muscles, ligaments, and bones in human limbs to identify which physical principles are used in their action;
- using a vector diagram to determine the resultant force acting on a tent pole due to a number of attached guy ropes.

Achievement Objective 7.2(a)

Students *could* be learning by:

- discussing the question: "What are the common themes of physics?";
- developing and testing their own general model of a method for carrying out scientific investigations;
- coming to a decision about whether there is a satisfactory answer to the question: "What is gravity?";
- participating in a class research project on models of the atom, where each group presents a short talk on their chosen physicist or atomic model, e.g., plum pudding model, Rutherford's experiments.

Achievement Objective 7.2(b)

Students *could* be learning by:

- discussing the merits of switching a town's electricity supply off at certain periods of the day to save power;
- using provided data to prepare for a class conference about possible solutions to the problem of radio-wave interference or pollution;
- reporting on aspects of car design that increase the safety of passengers during collisions;
- debating the topic: "That radioactive isotopes are a help to the world";
- considering how wheelchair or bicycle design has changed in the last twenty years due to both the technological applications of physics principles and to new materials;
- watching a video on the development of the washing machine to show how advances in physics-based technologies have improved household appliances;
- interviewing a town's electrical supply officer about future energy needs and possible developments.

Achievement Objective 7.3(a)

Students *could* be learning by:

- designing a method to investigate how the range of a projectile varies with the angle of projection;
- participating in a problem-solving exercise that uses golf-ball elastic as a bungee rope for an egg;
- carrying out an investigation to see how centripetal force varies with speed and suggesting improvements to the apparatus;
- designing a method to test the prediction of the landing position of a ball-bearing rolled horizontally from a table top;

- plotting and interpreting the voltage/current graphs for a variety of substances, e.g., ionic liquids, diodes, light bulbs;
- using a data logger to measure the force acting on a model figure as it is brought to rest at different rates in a simulated vehicle collision;
- videoing or photographing a netball's motion to see if the horizontal component of its velocity is indeed constant.

Achievement Objective 7.3(b)

Students could be learning by:

- attaching a potentiometer to an audio amplifier to form a volume control and comparing the output volume with the potentiometer setting;
- modifying a camera to take photographs under extreme conditions, e.g., close up, wide angle, low light;
- investigating the lighting system of a car;
- devising a method to test the accuracy of the power rating of a microwave oven by heating water;
- constructing an electric generator.

Assessment Examples

The following assessment activities are examples of tasks which teachers could devise to provide diagnostic, formative, or summative information in their own assessment programme. A small selection of aspects which teachers might choose to assess is provided for each of the example activities.

Achievement Objective 7.1(a)

- Students calculate the initial velocity of water from a fire hose, using data obtained from a given photograph or video image.

Using this example, teachers and students could assess the students' ability to:

- relate the principles and formulae of projectile motion to the situation;
- determine and apply a scale factor;
- take measurements from a photograph;
- make appropriate calculations.

- Students sit a written test on concepts, principles, and models used in explaining electrical circuits.

Using this example, teachers and students could assess the students' ability to:

- recall physical ideas related to the topic;

- apply physical ideas in familiar and unfamiliar situations;
- set out answers logically and clearly.
- Students construct a concept map on the topic of wave motion from a list of concepts, principles, and mathematical formulae given them.

Using this example, teachers and students could assess the students' ability to:

- make appropriate links between concepts and principles;
- use mathematical formulae, where appropriate, to show links between concepts and principles.

Achievement Objective 7.1(b)

- Students write a few paragraphs on the effect of artificial gravity in a rotating space station.

Using this example, teachers and students could assess the students' ability to:

- apply the concept of centripetal force in an unfamiliar context;
 - describe how physical principles can be used in a technological application.
 - Students determine the work done in digging a hole with a post-hole borer from data supplied.
- Using this example, teachers and students could assess the students' ability to:
- co-ordinate ideas of torque and work;
 - practise numeracy skills;
 - make sensible estimates.

Achievement Objective 7.2(a)

- Students write a brief account of Becquerel's discovery of radioactivity or the discovery of X-rays by Roentgen.

Using this example, teachers and students could assess the students' ability to:

- assess the role that chance can play in the discovery of new ideas in physics;
- relate developments in physics to their potential benefits for society;
- work independently.

- Students write a short essay comparing Aristotelian and Newtonian ideas of force and motion.

Using this example, teachers and students could assess the students' ability to:

- use empirical evidence to evaluate a theoretical idea;
- analyse the relative merits of alternative explanations.

- Students write notes on the Dalton, Thomson, and Rutherford models of the atom.

Using this example, teachers and students could assess the students' ability to:

- show how scientific explanations change and develop in the light of ongoing experimental research;
- organise information concisely and clearly.

Achievement Objective 7.2(b)

- Students watch and discuss a film such as *The China Syndrome* or *The Day After*.

Using this example, teachers and students could assess the students' ability to:

- appreciate hazards associated with the commercial or military uses of nuclear technology;
- contribute usefully to a discussion.

- Students read relevant newspaper articles or watch videos concerning a new development in a physics-based technology and present their findings to the class.

Using this example, teachers and students could assess the students' ability to:

- show how the development relies on physics principles;
- describe the way in which this technology impacts on the lives of people.

Achievement Objective 7.3(a)

- In groups, students design an investigation, using a video camera, to produce a velocity/time graph for a ball-bearing falling through oil.

Using this example, teachers and students could assess the students' ability to:

- plan and modify an experimental design until it works well;
- use graphical techniques to summarise and present experimental data;
- use mathematical techniques to identify the mathematical relationships present in experimental data;
- show initiative in solving practical problems.

- In groups, students design a means to measure the power output of a radio-controlled car.

Using this example, teachers and students could assess the students' ability to:

- apply the concepts of work and power to a practical situation;
- plan and execute an investigation;
- work to deadlines;
- show initiative;
- work co-operatively with other students.

- Students plan and carry out an investigation to establish how the resistance of a thermistor depends on the temperature.

Using this example, teachers and students could assess the students' ability to:

- design a circuit to collect data from which resistance can be determined;
- use apparatus and measuring instruments appropriately and effectively;
- graph data accurately;
- interpret their measured data.

Achievement Objective 7.3(b)

- Students design and build, to given specifications, a vehicle that uses the energy stored in a rubber band.

Using this example, teachers and students could assess the students' ability to:

- apply physical principles when problem solving;
- think laterally.

- Students simulate a child's mobile, using string, rulers, and masses.

Using this example, teachers and students could assess the students' ability to:

- use appropriate physical principles in designing the mobile;
- manipulate equipment and construct a well-balanced mobile;
- appreciate the limitations of principles when applied practically.

- Students investigate the construction of a water heater that switches off when the temperature reaches the desired level.

Using this example, teachers and students could assess the students' ability to:

- relate their understanding of electrical concepts and components to the design of a technological application.

PHYSICS: LEVEL 8 Form 7 Yr 13

Achievement Objectives

In the content areas listed below students can:

- 8.1 (a) demonstrate an understanding of concepts, principles, and models, *e.g.*, rotational inertia, resonance;
- (b) apply concepts and principles to explain physical phenomena, systems, and devices, *e.g.*, resonant circuits, nuclear reactors;
- 8.2 (a) appreciate the power and limitations of theories and models in physics, *e.g.*, approximations in Young's interference, limitations of the Bohr theory;
- (b) analyse developments in physics and physics-based applications and the influence of society on them, *e.g.*, the development of the laser and its use in medicine, solar cell technology;
- 8.3 (a) carry out practical investigations* to determine relationships, patterns, and trends in physical systems, *e.g.*, how period varies with length in the simple pendulum, factors affecting moment of inertia;
- (b) carry out practical investigations* to identify and explain applications of physical concepts and principles, *e.g.*, capacitance in camera flash units, wave motion in musical instruments.

*The achievement objectives for investigative skills at level 8 are outlined on pages 42 and 43.

CONTENT	SUGGESTED OPTIONAL CONTENT
Mechanics Circular motion under the influence of two or more forces, <i>e.g.</i> , conical pendulums, around banked corners etc; Kinematics equations for rotational and simple harmonic motions; Rotational inertia, relationship between torque and angular acceleration, rotational energy; Angular momentum and its conservation; Dynamics of simple harmonic motion, and conservation of energy in simple harmonic motion; Newton's Law of Gravitation and the idea of a gravitational field, satellites in circular orbits;	Conservation of momentum with respect to centre of mass motion; <i>Kepler's Laws;</i> Addition of simple harmonic motions; Gravitational potential energy in a radial field, escape velocity, the event horizon of a black hole;

CONTENT	SUGGESTED OPTIONAL CONTENT
Electricity Uniform electric fields and work done on charges that move in them, motion of a charged particle in a uniform field, potential difference, the electron volt; Capacitance, the capacitor and its practical forms; Rectifiers and capacitors in DC power supplies;	Computational Physics Computer modelling of physical phenomena (<i>e.g.</i> , projectile motion with significant air resistance); <i>Kirchhoff's Laws;</i> Operational amplifier circuits and logic circuits;
Electromagnetism Idea of flux, Faraday's Law, induced voltage in a coil rotating in a uniform magnetic field; Self and mutual inductance, the transformer; Idea of RMS equivalence, relationship between voltage and current in AC circuits containing resistors, capacitors, and inductors, LCR series resonant circuits;	Simple radio receiver and AM modulation;
Light and Waves Diffraction, Young's interference, diffraction gratings, interference of sound; Graphical description of travelling and standing waves, factors affecting the speed of waves in elastic media, beats; Doppler effect for a stationary observer;	Polarisation, thin film interference, phasor analysis of interference; Doppler red shift and the expanding universe, Doppler effect for a moving observer, production and nature of laser radiation;
Atomic and Nuclear Physics Atomic line spectra, idea of the photon, Bohr model of the hydrogen atom; Photo-electric effect, wave/particle duality of light; Binding energy, nuclear reactions, mass/energy conservation.	Relativity; Strong nuclear force and models of the nucleus.

Sample Learning Contexts

The violin and organ pipes • Nuclear hazards • Ultrasound scanning and radiotherapy
 Pendulums • The helicopter • Modern machinery • The heliocentric solar system
 Amusement park rides • Household technology • Sound reproduction
 Consumer electronics • Solar power • Physics in sports • Houses of the future
 Information technology • Physicists at work • New Zealand's power supply
 Satellites around the earth

Possible Learning Experiences

The following are examples of learning experiences teachers could choose to provide, depending on the resources available. These examples are suggestions only and are not intended to be prescriptive. A range, from tightly defined tasks to broad investigations, has been included. Even though these learning experiences are grouped under headings, a range of learning outcomes is possible from each learning experience.

Achievement Objective 8.1(a)

Students *could* be learning by:

- sitting on a rotating chair and moving weights from an arm's length on to their laps in order to experience conservation of angular momentum;
- comparing the similar patterns (analogies) that exist in explanations of gravitational and electrical fields;
- observing the shape of a uniform electric field by applying a large voltage across parallel plates placed in a dish of grass seed on oil;
- using a simple spectrometer to study the emission lines given off by various light sources, e.g., street lights, mercury lamps;
- using a computer spreadsheet to simulate and solve a Kirchhoff's Law problem;
- using free-body force diagrams to analyse problems such as cars moving around corners, satellites in orbit, roller coasters looping the loop;
- using an oscilloscope and microphone to examine audio wave forms produced by human voices and musical instruments;
- using a signal generator and two loudspeakers to set up a demonstration of sound interference patterns;
- observing the diffraction patterns made by shining laser light on a compact disc and participating in a discussion leading to ideas of interference;
- listening to a loudspeaker being whirled in a circle as an introduction to the Doppler effect and its applications;
- solving problems involving circuits containing capacitors, inductors, and resistors, such as high- and low-pass filters and resonant circuits;
- observing and discussing the emission of electrons from metals by certain frequencies of light to determine the conditions under which the classical wave model of light breaks down.

Achievement Objective 8.1(b)

Students *could* be learning by:

- finding out how bees use polarised light in the sky to navigate;
- explaining aspects of the design of a helicopter in terms of the principles of rotational motion;

- visiting a radio-therapy department of a hospital to see how cancer is treated using X-rays, high energy electrons, and gamma radiation;
- listening to loudspeakers with and without enclosure boxes, and discussing how interference considerations affect the design of speakers;
- reporting on how electrical generators are used in our national electricity supply;
- examining applications of AC resonance and induction in library and merchandise security systems;
- reading an article on the physics principles used in fire fighting;
- using the Doppler effect to estimate the speed of rotation of the sun from published spectral measurements taken from opposite ends of its diameter;
- observing another student demonstrating and explaining how the phenomenon of "beats" can be used to tune a guitar.

Achievement Objective 8.2(a)

Students *could* be learning by:

- considering the use of approximations when interpreting thin-film interference patterns;
- discussing the question: "Do we design models to fit in with our observations in nature or do we look for patterns in nature to fit our theories?";
- observing both the power and limitations of mathematical expressions in explaining physical phenomena, e.g., Balmer's empirical formula, formula for the period of a pendulum;
- considering simplifications and approximations made when describing wave phenomena;
- debating the statement: "Physics is a box of tools used to construct the true picture of the universe.";
- exploring the historical reasons for defining acceleration as change of velocity with time and not change of velocity with distance.

Achievement Objective 8.2(b)

Students *could* be learning by:

- choosing to research advantages and disadvantages to society of a physics-based technology such as: nuclear power, nuclear medicine, credit cards and EFTPOS machines, military hardware, arcade games, weather and communications satellites, space exploration, microwave heating and cooking, agricultural technology;
- considering the reaction of the Church to Copernicus' idea of the heliocentric universe;
- evaluating different energy sources and deciding on preferred ways for New Zealand to generate its future electrical power;

- finding out how social considerations influenced the decision not to install a food irradiation plant in New Zealand;
- finding a physicist or engineer in their local area and preparing a short essay on the physics site or he uses in their work;
- reading about how the need to transmit radio waves led to research in atmospheric physics;
- discussing the issues in physics, technology, and ethics encountered by people involved in the Manhattan Project during World War II.

Achievement Objective 8.3(a)

Students could be learning by:

- investigating the absorption in air of radiation from a commercial smoke detector by using a Geiger counter, and commenting on the safety of smoke detectors for the user;
- measuring the mass of an electron by observing the radius of the circle it moves in when travelling at a known speed inside a known magnetic field;
- using a sonometer and air columns to investigate resonant standing waves;
- investigating different harmonics produced by musical instruments;
- carrying out an extensive practical investigation of their choice on a physics topic negotiated with the teacher (which could take up to three weeks of class time), keeping a log book, and completing a full report as well as giving a presentation to the class on their work;
- photographing stress patterns in perspex rulers and stretched adhesive tape placed between crossed polarising filters;
- videoing and analysing the angular rotation of an ice skater, roller-skater, or diver from the high board;
- recording and analysing the action of a rower;
- gathering data from a long, heavy pendulum to plot distance/time, velocity/time, and acceleration/time graphs.

Achievement Objective 8.3(b)

Students could be learning by:

- researching and designing an electronic device that may be of benefit to the community (such as an alarm to come to a sick person's aid) and testing the device to determine its efficiency or limits of operation;
- constructing an example of fluid damping, and measuring its decay constant;
- constructing and calibrating a speedometer made from a magnet spinning near a metal disc;
- investigating the physical concepts and principles incorporated in the design of a selection of toys and games, e.g., the yo-yo;

- investigating how the different frequencies of violin strings are related to their length, thickness, and tension;
- designing suitable tests to analyse and explain the operation of a metal detector.

Assessment Examples

The following assessment activities are examples of tasks which teachers could devise to provide diagnostic, formative, or summative information in their own assessment programme. A small selection of aspects which teachers might choose to assess is provided for each of the example activities.

Achievement Objective 8.1(a)

- *Students use a computer spreadsheet that mathematically depicts a moving sound source passing a stationary observer.*

Using this example, teachers and students could assess the students' ability to:

- enter realistic initial positions, velocity, and frequency;
- interpret the graph of observed frequency against time produced;
- investigate and interpret extreme conditions such as the effect when the moving source is travelling at a speed near that of sound;
- modify the spreadsheet to add an acceleration factor in the moving source's motion;
- suggest further possible examples of spreadsheet simulations.

- *Students answer a set of written questions about nuclear reactions.*

Using this example, teachers and students could assess the students' ability to:

- plan a method to solve the problems;
- choose appropriate formulae to calculate a solution;
- lay out the solution clearly and logically;
- check the method by checking the feasibility of the final answer.

- *Students watch a video on electromagnetic induction.*

Using this example, teachers and students could assess the students' ability to:

- absorb visual information about an unfamiliar topic by completing a worksheet of questions based on the video;
- formulate questions in order to clarify their understanding.

Achievement Objective 8.1(b)

- *Students observe and discuss the motion of a range of children's spinning tops taken from various cultures.*

Using this example, teachers and students could assess the students' ability to:

- make relevant observations of the tops' motion;

- contribute to a discussion on the motivation behind the development or drawbacks; - communicate their findings and evaluations with clarity.	• <i>Students present a seminar on research and development in radiation safety standards in industry or medicine.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- relate how society's expectations can focus physics research; - recognise the interaction between physics and biology in this form of research; - present relevant information to class members during a three-minute presentation.	- relate how society's expectations can focus physics research; - recognise the interaction between physics and biology in this form of research; - present relevant information to class members during a three-minute presentation.
Achievement Objective 8.3(a)	Achievement Objective 8.3(a)
• <i>In groups, students carry out an investigation on a physical system to decide if it is simple harmonic.</i>	• <i>In groups, students carry out an investigation on a physical system to decide if it is simple harmonic.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- analyse motion to predict the appropriate measurements required; - design the apparatus set-up in order to take the appropriate measurements; - identify the key characteristics of simple harmonic motion; - recognise limitations in their data gathering.	- analyse motion to predict the appropriate measurements required; - design the apparatus set-up in order to take the appropriate measurements; - identify the key characteristics of simple harmonic motion; - recognise limitations in their data gathering.
• <i>Students independently carry out a short project investigation to determine the acceleration due to gravity.</i>	• <i>Students independently carry out a short project investigation to determine the acceleration due to gravity.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- meet deadlines for planning, performing, and reporting the investigation; - organise and use all the required equipment; - quantitatively assess the uncertainties in the investigation.	- meet deadlines for planning, performing, and reporting the investigation; - organise and use all the required equipment; - quantitatively assess the uncertainties in the investigation.
• <i>Students connect an inductor, capacitor, and resistor to a signal generator and observe the variation in voltages across the resistor and generator as frequency is varied.</i>	• <i>Students connect an inductor, capacitor, and resistor to a signal generator and observe the variation in voltages across the resistor and generator as frequency is varied.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- construct a circuit from a given diagram; - relate observed wave forms and phases to relevant relationships in AC circuits; - determine the resonant frequency from the observed wave forms.	- construct a circuit from a given diagram; - relate observed wave forms and phases to relevant relationships in AC circuits; - determine the resonant frequency from the observed wave forms.
• <i>Students perform Young's experiment to measure the wavelength of light, using a laser.</i>	• <i>Students perform Young's experiment to measure the wavelength of light, using a laser.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- work from written instructions;	- work from written instructions;

- apply known physical principles to a new situation; - relate the situation to more complex applications of gyroscopic motion; - listen to other students' ideas and opinions.	• <i>In groups, students research and present a three-minute talk on a practical application of electrical resonance.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- assess the individual strengths of members of the group in assigning the specific tasks of researching, preparing, and delivering the presentation.	- assess the individual strengths of members of the group in assigning the specific tasks of researching, preparing, and delivering the presentation.
• <i>Students calculate the appropriate banking angle for a car travelling around a bend at a given speed.</i>	• <i>Students calculate the appropriate banking angle for a car travelling around a bend at a given speed.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- co-ordinate ideas of centripetal force, components of vectors, and trigonometry in order to analyse a physical system; - practice numeracy skills; - make sensible estimates.	- co-ordinate ideas of centripetal force, components of vectors, and trigonometry in order to analyse a physical system; - practice numeracy skills; - make sensible estimates.
Achievement Objective 8.2(a)	Achievement Objective 8.2(a)
• <i>Students choose a theory or law already studied and analyse its use.</i>	• <i>Students choose a theory or law already studied and analyse its use.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- recognise the approximations made that enable simple explanations for school level; - describe the limitations of the law or theory.	- recognise the approximations made that enable simple explanations for school level; - describe the limitations of the law or theory.
• <i>Students write a one page essay analysing the statement: "If our guesses can accurately predict the outcome of an experiment, then our guesses must be the truth".</i>	• <i>Students write a one page essay analysing the statement: "If our guesses can accurately predict the outcome of an experiment, then our guesses must be the truth".</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- prepare a well reasoned argument for or against the statement.	- prepare a well reasoned argument for or against the statement.
Achievement Objective 8.2(b)	Achievement Objective 8.2(b)
• <i>Students evaluate and report on how the current need for energy has led to research into alternative energy generation or supply, and into more efficient use of energy in the home, industry, and transport.</i>	• <i>Students evaluate and report on how the current need for energy has led to research into alternative energy generation or supply, and into more efficient use of energy in the home, industry, and transport.</i>
Using this example, teachers and students could assess the students' ability to:	Using this example, teachers and students could assess the students' ability to:
- recognise factors influencing the demand for energy; - recognise physical principles involved in energy transformations; - evaluate current viability of various energy generation technologies; - report their findings accurately and concisely.	- recognise factors influencing the demand for energy; - recognise physical principles involved in energy transformations; - evaluate current viability of various energy generation technologies; - report their findings accurately and concisely.

DEVELOPING SCIENTIFIC INVESTIGATIVE SKILLS AND ATTITUDES IN PHYSICS

In practice, physics as a process involves an integration of knowledge, skills, and attitudes to develop scientific understanding. Practical work in physics can include experiencing phenomena, developing practical skills or techniques, and carrying out investigations. Investigations provide key opportunities for students to extend their understanding in science. They also enable students to develop the scientific skills and attitudes required to enhance their ability to explore phenomena and events and to solve problems. It can be expected that as they learn, students will show an increasing sophistication in the skills they use in their investigations.

Carrying out an investigation in science involves an interaction of many complex skills. These include focusing, planning, information gathering, processing, interpreting, and reporting. Students may be investigating by carrying out a practical investigation of the "real world", by carrying out an investigation of appropriate reference material, or by integrating these approaches.

Problem solving is an essential part of scientific investigation. Problem solving includes identifying and analysing the problem, gathering relevant information, designing alternative solutions, testing the method or device, evaluating the method or device, modifying the method or device, and reaching a decision regarding the merit of the chosen method or device.

As students learn in physics, they should be encouraged to develop the attitudes on which scientific investigation depends. These attitudes include curiosity, honesty in recording and validation of data, flexibility, persistence, critical-mindedness, open-mindedness, willingness to suspend judgment, willingness to tolerate uncertainty, and an acceptance of the provisional nature of scientific explanation.

Other attitudes which arise out of reflection about the past, present, and future involvement of physics in social and political affairs should also be encouraged. These include a positive and responsible regard for both the living and non-living components of the Earth's environment, and a desire for critical evaluation of the consequences of applying discoveries in physics.

The possible learning experiences detailed in this section are organised in relation to clusters of specific investigative skills (focusing and planning, information gathering, processing and interpreting, reporting). Each learning experience is linked to an achievement objective(s). These are shown in brackets. The first number indicates the level, either 6, 7 or 8. The second and third number or letter indicates the objective at that level.

- make accurate measurements;
- manipulate equipment efficiently;
- apply theoretical ideas in practical situations.

- *Students perform an investigation to identify the variables that affect the frequency of the sound produced by a guitar string.*

Using this example, teachers and students could assess the students' ability to:

- apply known physical principles to a new situation;
- isolate and control variables;
- demonstrate an organised, independent approach to planning an investigation.

- *Students investigate the efficiency of a solar cell.*

Using this example, teachers and students could assess the students' ability to:

- be persistent in their investigation;
- come to a decision on the meaning of "efficiency";
- apply known physical principles to a new situation;
- combine principles from different areas of physics;
- communicate their findings with clarity.

Achievement Objective 8.3(b)

- *Students design and carry out a method to measure the angular acceleration of a washing machine at the start of its spin cycle.*

Using this example, teachers and students could assess the students' ability to:

- apply known physical principles to a new situation;
- combine principles from different areas of physics;
- design the apparatus set-up in order to take appropriate measurements.

- *Using their knowledge of capacitance, students design a simple camera flash to meet certain specifications.*

Using this example, teachers and students could assess the students' ability to:

- draw a circuit diagram;
- solder components together to produce a working circuit from the circuit diagram;
- change components to meet a change in specifications.

Achievement Objectives

Levels 5 and 6	Processing and Interpreting	Reporting
	Students will be achieving at level 6 when they can: - analyse recorded data using statistical and graphing procedures, as appropriate, to identify trends, relationships, and patterns; - compare their findings or possible solutions with established scientific theory to draw and justify conclusions.	Students will be achieving at level 6 when they can: report in a well reasoned, concise manner, using appropriate media, with conclusions that are justified and supported by relevant data.
Levels 7 and 8	Processing and Interpreting	Reporting
	Students will be achieving at level 8 when they can: - analyse recorded data using statistical and graphing procedures, as appropriate, to identify trends, relationships and patterns; - compare their findings or possible solutions with established scientific theory to draw and justify conclusions; - evaluate the reliability and validity of their findings or possible solutions using statistical procedures where appropriate.	Students will be achieving at level 8 when they can: - report in a well reasoned, concise manner, using appropriate media, with conclusions that are justified and supported by relevant data; - report on the reliability and validity of their findings or possible solutions, with supporting evidence showing the evaluation of data using statistical procedures where appropriate.

Notes:

1. Refer to *Science in the New Zealand Curriculum* for achievement objectives below level 5.
2. The ability to carry out a complete investigation is the key expected outcome of this achievement aim.
3. It is expected that students will develop any specific investigative skills they need when they are carrying out a complete investigation.
4. The processes of investigation are not necessarily sequential. The process may begin at any point in the above framework and will tend to move backwards and forwards. Students should be reflecting on their decisions, actions, and findings and be modifying their plans and actions as they are proceeding.

DEVELOPING SCIENTIFIC INVESTIGATIVE SKILLS AND ATTITUDES IN PHYSICS

Achievement Objectives

Levels 5 and 6	Focusing and Planning	Information Gathering
	Students will be achieving at level 6 when they can: - ask a series of related questions of themselves, their group, and resource people, and refine questions to make them suitable for scientific investigation; - integrate their scientific ideas and personal observations with the scientific ideas of others to make testable predictions or to identify possible solutions for trialling; - design 'fair tests', simple experiments, trials, and surveys, with clear specification and control of likely variables.	Students will be achieving at level 6 when they can: - select and use equipment to make qualitative and quantitative observations and measurements with appropriate precision; - carry out procedures to systematically observe and record information and measurements; - locate and process relevant information using a variety of sources, such as books, newspapers, periodicals, catalogues, indexes, and computers.
Levels 7 and 8	Focusing and Planning	Information Gathering
	Students will be achieving at level 8 when they can: - ask a series of related questions of themselves, their group, and resource people, and refine questions to make them suitable for scientific investigation; - integrate their scientific ideas and personal observations with the scientific ideas of others to make testable predictions or to identify possible solutions for trialling; - design systematic tests, experiments, trials, and surveys with rigorous identification and control of variables.	Students will be achieving at level 8 when they can: - select and use equipment to make qualitative and quantitative observations and measurements with appropriate precision; - carry out procedures to systematically observe and record information and measurements; - locate and process relevant information using a variety of sources, such as books, newspapers, periodicals, catalogues, indexes, and computers; - evaluate the quality of information gathered and its degree of relevance.

Possible Learning Experiences Related to Focusing and Planning

Information gathering in physics may include:	Students could be learning by:
• using prior knowledge and experiences; • clarifying ideas; • integrating ideas from several sources; • having hunches and making guesses; • being curious and asking questions; • reframing questions so they can be investigated; • identifying, defining, and analysing the problem; • considering scientific models and laws; • predicting; • observing; • being open-minded; • being co-operative; • designing a systematic investigation (including designing an experiment); • making decisions about the feasibility of an investigation; • being flexible; • deciding whether an "expert" needs to be contacted; • re-designing an experiment when preliminary results are inconclusive; • being persistent.	• clarifying their ideas about the factors influencing the period of a pendulum (8.3a); • establishing the criteria to assess flight characteristics when carrying out a "fair test" of paper darts (7.3b); • designing a technique for measuring the number of revolutions per second a washing machine makes when on its spin cycle (7.3b); • planning an electrical wiring system for a model house (6.3b); • developing a flow chart to show the expected directions in the process of an investigation (6.7, or 8); • deciding where relevant information regarding the electrical characteristics of a light emitting diode can be found (7.3b); • asking an expert about various types of car safety devices (6.3b); • designing a method to measure the heat retention of a bedroom (6.3b); • asking questions about which factors affect the light intensity of a lamp (7.3a); • making predictions about the position and size of the image formed when a candle is placed in front of a concave mirror (7.3a); • predicting which of a range of physical factors influence the time taken for a cylinder to roll down a slope (8.3a); • using library information search techniques when planning a science project on superconductors (7.3b); • deciding if it is safe to carry out an investigation into the efficiency of a transformer (8.3a); • reading a range of journals and newspaper articles when beginning a study on medical uses of ultrasound (6.1b).

Possible Learning Experiences Related to Information Gathering

Information gathering in physics may include:	Students could be learning by:
• exploring; • observing; • seeking patterns/relationships; • testing ideas, predictions, and explanations; • organising resources; • conducting experiments; • testing methods or devices; • identifying and controlling variables; • constructing or manipulating equipment; • locating, collecting, and recording data; • searching for an answer to a problem or question; • designing a device to meet a specified function; • being honest in the recording and validation of data; • being persistent; • deciding what information is required; • deciding when to ask an "expert"; • selecting information from a variety of sources; • using information-retrieval and information-processing technologies; • recording raw and processed data; • linking "old" and "new" ideas; • evaluating gathered information.	• collecting data from tests of an elastic-propelled vehicle (6.3b); • looking for nodal lines in the pattern of ripples seen in a ripple tank (8.3b); • recording the pattern a tuning fork makes on water (7.3b); • seeking reasons why board sailors wear wet suits in the summer (6.3b); • building a waka, from harakeke, which will hold 500 grams (6.3b); • collecting data about the rate in which a trolley slows down on different surfaces (6.3a); • building a model electric motor (6.3b); • finding an answer to the question of why soap films are multi-coloured (8.1b); • using an oscilloscope to record sound patterns produced by different musical instruments (8.3b); • deciding what questions to ask the guide at a hydro-electric power station (8.3b); • comparing "before and after" views about the acceleration of objects moving in a circle (7.1a); • using the local council library to obtain information to prepare for a project on applications of polarisation (8.3b); • using the microfiche/CD ROM in a library to access information about electronic thermometers (8.3b); • interviewing a kaumatua about Maori tops (8.3b); • deciding what information is required to make appropriate planning decisions for an investigation into the stability of bicycles (8.3b); • evaluating gathered information about the effect of pressure on a fixed volume of air in a syringe (7.3a).

Possible Learning Experiences Related to Processing and Interpreting

Processing and Interpreting in physics may include:	Students could be learning by:
- processing data; - synthesising data; - linking new and old ideas; - discussing ideas; - negotiating an understanding; - identifying patterns and relationships; - suggesting possible explanations; - critiquing the method; - analysing a device; - being critically minded; - evaluating processed data; - trying to resolve any incongruity in ideas and concepts; - justifying inferences in the light of gathered data; - appreciating and expressing limitations of experimental procedures and gathered data; - being intellectually honest; - being open-minded; - detailing a solution to the problem; - reflecting on your own thinking; - being willing to suspend judgment; - being willing to tolerate uncertainty; - accepting the provisional nature of scientific explanation; - accepting the validity of the results and conclusions of others.	- discussing ideas about the density of various woods (6.3a); - developing an explanation for the fringe pattern seen in a vertical soap film (8.3a); - evaluating findings about which tested method is the most accurate to determine the acceleration due to gravity (6.3a); - interpreting the class's monthly data on inside and outside temperatures (6.3a); - reaching a consensus about the size of the uncertainty when using a stopwatch (6.2a); - deciding whether to endorse the use of radioactive sources in smoke detectors (7.2b); - discussing ideas about processed data on voltage changes in a battery over time (7.3a); - linking ideas about images formed in glass lenses with the way an eye works (6.3b); - putting together gathered data on the time taken by model cars to travel down a variety of inclines (6.3a); - interpreting a print-out of a seismograph recording (8.3a); - resolving the conflict arising when two patterns emerge in the worked data gathered from experiments measuring the electric field at points between two electrodes placed in a copper sulfate solution (8.3a); - selecting the best explanation for the relative strengths established from a series of experiments on differently constructed electromagnets (7.3b); - recognising that the data collected is insufficient to enable confident statements to be made about the resistivity of a sample of play-dough (7.3a); - identifying the relationship between the length of a vibrating wire and its fundamental resonant frequency (8.3a); - evaluating conflicting ideas about the safety of microwaves (7.1b).

Possible Learning Experiences Related to Reporting

Reporting in physics may include:	Students could be learning by:
- sharing findings — in writing, orally, visually, graphically, symbolically, diagrammatically, as models; - using a wide range of media including — computers, videotape recordings, audiotape recordings, a range of publishing methods, performance arts.	- using a computer spreadsheet programme to display the relationships between light intensity, surface area, and electrical voltage generated for a solar cell (7.3b); - presenting measurements of voltage and time taken from the discharge of a capacitor in the form of a graph (8.3a); - making a video clip about the motion of a single skull rower (8.3b); - using a desk-top publishing program to compile a report on a "fair test" they have carried out on insulating materials (6.3b); - writing an article for the local newspaper about recent developments in contact lenses (6.1b); - preparing a display for a science fair summarising their investigation into noise levels at various places in a local factory (8.3b); - submitting a report to the <i>New Zealand Science Teachers' Association Journal</i> summarising their investigation into testing and improving biro springs (7.3b).

PHYSICS ACHIEVEMENT OBJECTIVES

LEVEL 6

In the content areas listed below students can:

- 6.1 (a) demonstrate an understanding of concepts, principles, and models, *e.g.*, *Newton's Laws, conceptual models for electric current*;
 (b) apply concepts and principles to explain physical phenomena, systems, and devices, *e.g.*, *loudspeakers, hairdryers*;
- 6.2 (a) explore the use of experimental evidence in developing theories and models, *e.g.*, *number of measurements needed to determine a relationship, reliability of data*;
 (b) describe influences of everyday physics-based applications on their lives, *e.g.*, *spectacles, light bulbs, the combustion engine*;
- 6.3 (a) carry out practical investigations to determine relationships, patterns, and trends in physical systems, *e.g.*, *frictional forces and type of surface, graphing temperature changes*;
 (b) carry out practical investigations to explore applications of physical concepts and principles, *e.g.*, *the optical system of an overhead projector*.

Content

Mechanics

Displacement, velocity, acceleration, and graphical representation of motion in one dimension;
 Newton's First and Second Laws and ideas of resultant forces and equilibrium of forces;
 Frictional forces and free body force diagrams;
 Mass, weight, and the acceleration due to gravity;
 Pressure and density;
 Work and power, gravitational potential energy, kinetic energy, and the conservation of mechanical energy;

Electricity

Idea of positive and negative charge, electrostatic forces, conductors and insulators;
 Conceptual model for the behaviour of simple circuits using ideas of current, voltage, resistance, and series and parallel connection of resistors;
 Graphical representation of the relationship between current and voltage in ohmic conductors;
 Energy dissipation and power in resistors;

Electromagnetism

Magnetic fields due to current in wires and solenoids;
 Magnetic force on a current carrying wire;
 The simple DC motor;

Heat

LEVEL 7

In the content areas listed below students can:

- 7.1 (a) demonstrate an understanding of concepts, principles, and models, *e.g.*, *conservation of momentum, centripetal force*;
 (b) apply concepts and principles to explain physical phenomena, systems, and devices, *e.g.*, *fibre optics, bicycle dynamics*;
- 7.2 (a) describe how physical theories and models have developed, *e.g.*, *the development of increasingly sophisticated atomic models*;
 (b) explain how developments in physics-based applications can lead to changes in society, *e.g.*, *the effect of the electric motor on home life, the effect of the combustion engine on the mobility of people*;
- 7.3 (a) carry out practical investigations to determine relationships, patterns, and trends in physical systems, *e.g.*, *light intensity changes, measuring g* ;
 (b) carry out practical investigations to identify and describe applications of physical concepts and principles, *e.g.*, *thermostats, volume controls*.

Content

Mechanics

Kinematics equations for translational motion in one dimension;
 Relative motion, including the addition and subtraction of vectors;
 Components of vectors, projectile motion, and circular motion;
 Levers, torque, and the principle of moments;
 Momentum and its conservation, impulse, and Newton's Third Law of Motion;
 Energy changes in elastic and inelastic collisions, Hooke's Law and elastic potential energy;

Electricity

Quantitative analysis of currents, voltages, and power dissipation in series/parallel circuits using Ohm's Law;
 Voltage dividers;
 Properties of non-ohmic conductors such as light emitting diodes, light dependent resistors, thermistors;

Electromagnetism

Quantitative treatment of the magnetic force on a current carrying conductor;
 Force on a charged particle moving in a magnetic field;
 Induced voltage generated across a straight conductor moving in a uniform magnetic field, simple generators;

Light and Waves

LEVEL 8

In the content areas listed below students can:

- 8.1 (a) demonstrate an understanding of concepts, principles, and models, *e.g.*, *rotational inertia, resonance*;
 (b) apply concepts and principles to explain physical phenomena, systems, and devices, *e.g.*, *resonant circuits, nuclear reactors*;
- 8.2 (a) appreciate the power and limitations of theories and models in physics, *e.g.*, *approximations in Young's interference, limitations of the Bohr theory*;
 (b) analyse developments in physics and physics-based applications and the influence of society on them, *e.g.*, *the development of the laser and its use in medicine, solar cell technology*;
- 8.3 (a) carry out practical investigations to determine relationships, patterns, and trends in physical systems, *e.g.*, *how period varies with length in the simple pendulum, factors affecting moment of inertia*;
 (b) carry out practical investigations to identify and explain applications of physical concepts and principles, *e.g.*, *capacitance in camera flash units, wave motion in musical instruments*.

Content

Mechanics

Circular motion under the influence of two or more forces, *e.g.*, conical pendulums, around banked corners etc;
 Kinematics equations for rotational and simple harmonic motions;
 Rotational inertia, relationship between torque and angular acceleration, rotational energy;
 Angular momentum and its conservation;
 Dynamics of simple harmonic motion, and conservation of energy in simple harmonic motion;
 Newton's Law of Gravitation and the idea of a gravitational field, satellites in circular orbits;

Electricity

Uniform electric fields and work done on charges that move in them, motion of a charged particle in a uniform field, potential difference, the electron volt;
 Capacitance, the capacitor and its practical forms;
 Rectifiers and capacitors in DC power supplies;

Electromagnetism

Idea of flux, Faraday's Law, induced voltage in a coil rotating in a uniform magnetic field;

Heat Heat and temperature; Conduction, convection, and radiation of heat; Light and Waves Convex and concave lenses, and their applications; Longitudinal and transverse waves: period, wavelength, frequency, amplitude, speed, and their relationships; Atomic and Nuclear Physics Atomic no., mass no., isotopes, nuclear fission, and nuclear reactors.	Light and Waves Reflection and refraction of light and water waves; Superposition of waves; The electromagnetic spectrum; Atomic and Nuclear Physics Atomic models; Radioactive decay, half life and alpha, beta, and gamma emissions.	uniform magnetic field; Self and mutual inductance, the transformer; Idea of RMS equivalence: relationship between voltage and current in AC circuits containing resistors, capacitors, and inductors, LCR series resonant circuits; Light and Waves Diffraction, Young's interference, diffraction gratings, interference of sound; Graphical description of travelling and standing waves, factors affecting the speed of waves in elastic media, beats; Doppler effect for a stationary observer; Atomic and Nuclear Physics Atomic line spectra, idea of the photon, Bohr model of the hydrogen atom; Photo-electric effect, wave/particle duality of light; Binding energy, nuclear reactions, mass/energy conservation.
DEVELOPING SCIENTIFIC INVESTIGATIVE SKILLS AND ATTITUDES		
LEVELS 5 AND 6		
Focusing and Planning Students will be achieving at level 6 when they can: - ask a series of related questions of themselves, their group, and resource people and refine questions to make them suitable for scientific investigation; - integrate their scientific ideas and personal observations with the scientific ideas of others to make testable predictions or to identify possible solutions for trialling; - design "fair tests", simple experiments, trials, and surveys with clear specification and control of likely variables.	Processing and Interpreting Students will be achieving at level 6 when they can: - analyse recorded data, using statistical and graphing procedures, as appropriate, to identify trends, relationships, and patterns; - compare their findings or possible solutions with established scientific theory to draw and justify conclusions.	Reporting Students will be achieving at level 6 when they can: report in a well reasoned, concise manner, using appropriate media, with conclusions that are justified and supported by relevant data.
Information Gathering Students will be achieving at level 6 when they can: - select and use equipment to make qualitative and quantitative observations and measurements with appropriate precision; - carry out procedures to systematically observe and record information and measurements; - locate and process relevant information, using a variety of sources, such as books, newspapers, periodicals, catalogues, indexes, and computers.	Information Gathering Students will be achieving at level 6 when they can: - select and use equipment to make qualitative and quantitative observations and measurements with appropriate precision; - carry out procedures to systematically observe and record information and measurements; - locate and process relevant information, using a variety of sources, such as books, newspapers, periodicals, catalogues, indexes, and computers; - evaluate the quality of information gathered and its degree of relevance.	Information Gathering Students will be achieving at level 6 when they can: - select and use equipment to make qualitative and quantitative observations and measurements with appropriate precision; - carry out procedures to systematically observe and record information and measurements; - locate and process relevant information, using a variety of sources, such as books, newspapers, periodicals, catalogues, indexes, and computers; - evaluate the quality of information gathered and its degree of relevance.
LEVELS 7 AND 8		
Focusing and Planning Students will be achieving at level 8 when they can: - ask a series of related questions of themselves, their group, and resource people and refine questions to make them suitable for scientific investigation; - integrate their scientific ideas and personal observations with the scientific ideas of others to make testable predictions or to identify possible solutions for trialling; - design systematic tests, experiments, trials, and surveys with rigorous identification and control of variables.	Processing and Interpreting Students will be achieving at level 8 when they can: - analyse recorded data using statistical and graphing procedures, as appropriate, to identify trends, relationships, and patterns; - compare their findings or possible solutions with established scientific theory to draw and justify conclusions; - evaluate the reliability and validity of their findings or possible solutions, using statistical procedures where appropriate.	Reporting Students will be achieving at level 8 when they can: - report in a well reasoned, concise manner, using appropriate media, with conclusions that are justified and supported by relevant data; - report on the reliability and validity of their findings or possible solutions, with supporting evidence showing the evaluation of data, using statistical procedures where appropriate.

APPENDIX B: Sample letter for teachers' informed consent

APPENDIX B

The University of Waikato

Te Whare Wānanga o Waikato

Centre for Science, Mathematics and Technology Education Research

Te Kauhanganui o te Pangarau, te Pūtaiao me te Hangarau Rangahau Mātauranga

Private Bag 3105, Hamilton, New Zealand

Telephone (07) 856 2889, Centre direct line (07) 838 4035, Centre Fax (07) 838 4272

"Analysis of the Development and Implementation of the new Physics Curriculum" Research Project Information Sheet

Dear <Teacher >

Thank you for agreeing to support this project by being interviewed on your views about the new physics curriculum. The interview will take the form of a tape-recorded, informal discussion lasting for about 45 – 60 minutes.

This initial series of interviews with physics teachers is part of a longer term study that explores the issues involved in the development and implementation of a new curriculum, in particular the senior physics curriculum. I have had discussions with curriculum writers and science advisors. At this stage, I am interested to elicit your views as a physics teacher on the Physics in the NZ Curriculum statement and matters related to physics teaching and learning. There is no commitment on your part at this stage to be involved in the longer term project.

Please note that:

- * you nor your school will be identified at any stage during this research.
- * the interview will be transcribed into written form and you will have the opportunity to clarify, check the accuracy, and comment further on the discussion.
- * you are free to opt out of the interview at any stage.

With thanks in advance for your help,

Teresa S. Fernandez

"Analysis of Development and Implementation of the new Physics Curriculum" Research Project Consent Form.

I have read and understood the above conditions and I agree to be interviewed.

Teacher: _____ Signature: _____

School : _____ Date : _____

APPENDIX C :Schedules of Interview Questions

- C1** Interview Questions for Writers
- C2** Interview Questions for Teachers (Interview 1, end of 1996)
- C3** Interview Questions for Teachers (Interview 2, mid-1998)
- C4** Interview Questions for Teachers (Interview 3, end of 1998)

APPENDIX C1

Interview Questions for Curriculum Writers (conducted late 1996)

1. How were you chosen? What were the guidelines that the Ministry required you to work within? What was contained in the contract?
2. Can you explain to me the process by which the document was generated?
3. What were the constraints that you faced in the writing task of the curriculum statements, e.g., constrained by strands, stipulated levels, curriculum framework, *Science in the New Zealand Curriculum*, time, resources, feedback?
4. Did you have any model of curriculum design in mind when planning and writing the curriculum? How much choice did you have in utilising a model ? What were some of the problems involved in following a model of curriculum design?
5. Was there a problem in visualising what the final document would look like? Such as: *What* might be the specific content? *How* might teachers use it in the classrooms? *How* might students respond to it?
6. Why was it decided not to include a list of compulsory content in the draft statement? Were you comfortable with this decision?
7. How were the achievement objectives arrived at? Was the choice governed by your views about teaching and learning of Physics? Did you want to promote a certain approach to learning in the document? How much were you constrained by or wanted to address existing custom and practice? How much did traditional views about what is important in Physics learning influence you?
8. Are there new areas (content as well as approaches) that were incorporated into the new physics curriculum? or In what respect is this new physics curriculum different from the previous ones?

9. What are your views on compulsory or prescriptive curriculum and open-ended curriculum ? In the Physics curriculum statement, was there some leeway for teachers to infuse their own interpretation of the curriculum? If so was this a conscious decision by the writers?
10. Where did you get your ideas from for the content, sample learning contexts, possible learning experiences, and assessment examples? How much did the old Physics prescriptions influence the present document?
11. How did the feedback from the submissions to the draft statement affect the writing of the final statement?
12. How did the curriculum writers reach consensus? How is this consensus translated to the final written document?
13. What has been your personal influence on the final document? (Apart from writing it of course)
14. What does the word 'curriculum' mean to you? What definition of curriculum are you comfortable working with? (Compare with prescription)
15. How did your views about the role of schools in society influence your writing? What are your conceptions of the learner? How did your view of the nature of knowledge influence your writing?
16. Can you tell me what you feel about the assessment examples in the Physics document? How do they relate to the School Certificate and Bursary Physics Examinations? Were you concerned about the assessment needs when writing the curriculum statement?
17. What are your views about the unit standards and their suitability as an evaluation of learning under the new curriculum?
18. What measures do you think should be taken to ensure that the proposed Physics curriculum is implemented effectively in the classrooms?

19. What was the political context in which these curriculum changes were initiated?
20. Who were the major pressure groups or stakeholders?
21. How much consultation with teachers and other interested parties occurred? Were you satisfied with the extent of consultation that occurred?
22. Did the research findings on science education have an impact on the development of the Physics in the New Zealand Curriculum statement, e.g., work done in SERU and CSMER?
23. Some people have commented that there were tensions within the Physics curriculum statement, for example, the learning contexts being based on constructivist ideas and the achievement objectives being more hierarchical and neo-behavioural; science for all and science for scientists, listing skills and knowledge separately, etc. What are your views on these? Were they conscious and deliberate attempts to acknowledge the various views about science education?
24. The wider aims expressed in the *Science in the New Zealand Curriculum* statement, e.g., Girls and Science, Maori and Science, etc., were not focused on in the Physics document except for one paragraph at the beginning of page 7. Was this done deliberately? I.e., Were these aims not considered as important or relevant in senior Physics or were these aims incorporated into the curriculum writing without being expressly discussed as aims?
25. What is your vision of the ideal Physics curriculum in New Zealand secondary schools?

APPENDIX C2

Interview Questions for Physics teachers (Interview 1, Term 4, 1996)

Physics in the New Zealand Curriculum:

- How much do you know about the document?
- What do you like/dislike about it?
- What's not clear in it?
- What else to be included in it?
- How much teacher involvement in the production of the document?

Professional development:

- What have you done so far? (Formal/Informal)
- How were they helpful?

Assessment:

- What do you think of the assessment examples in the document
- What are your views about Unit Standards
- How important is assessment in your teaching programme?

Physics teaching:

- What is your main method of teaching physics at present?
- Do you see the document as promoting any particular method?
- Do you see a role for investigations in your physics lessons?
- What is important in learning physics?
- What is your vision of an ideal physics curriculum in senior secondary school?

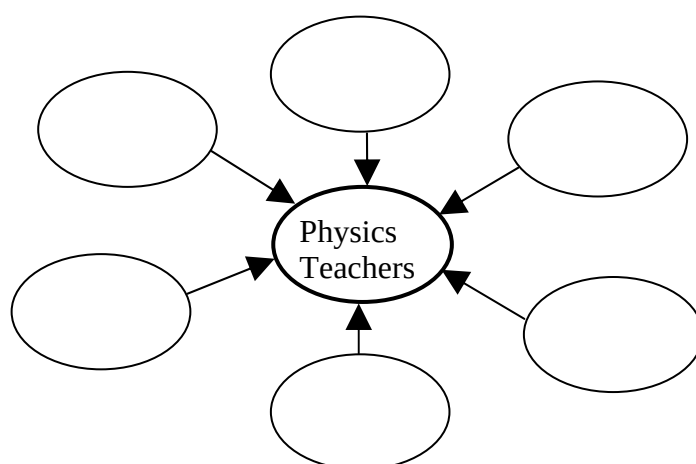
Issues/Debates about physics education:

- Physics for all or for more able students?
- Why is physics considered a difficult subject?
- Equity issues – low representation of Maori/Pacific Islands students and girls.
- Why study senior school physics; is it necessary to live in today's world?
- Content versus process in physics.
- Conceptual versus mathematical in physics.
- Physics versus technology.
- Orientate physics teaching for careers
- Reduced content – what should go?

APPENDIX C3

Interview Questions for Physics Teachers (Interview 2, Term2/3, 1998)

1. How did you come to understand the curriculum document? What happened in 1997 as part of your professional development?
2. In planning your new school teaching scheme for physics, what were your main considerations? How did you write it? What help did you receive?
3. What are the significant changes made when you compare the old school scheme with the new one for this year? (In terms of topics, teaching styles, assessment, assignments.)
4. How is it all going, the planned implementation and the actual implementation?
5. What aids the implementation? What hinders the implementation?
6. What do you think you would need so as to better implement the new curriculum?
7. What factors are impacting on you as a physics teacher in the process of implementing the new curriculum at this stage? You can show this by filling the simple diagram below.



8. Could you describe the history of change that you have undergone as a physics teacher, in terms of your teaching styles, your views of physics, of teaching and learning, and assessment?

APPENDIX C4**Interview Questions for Physics teachers (Interview 3, Term 4 (end), 1998)**

1. How has this year gone for you in terms of your physics teaching? What worked well and what did not? What were the problems that you faced?
2. When you compare the physics curriculum taught this year with your old curriculum, how is it different and how is it similar? (In terms of content, approach and assessment)
3. When you compare the physics curriculum taught this year with the new curriculum as described in the physics document, how is it similar and how is it different? (In terms of content, approach and assessment)
4. What would you like to do differently?
5. What direction would you like your physics curriculum to take next year and the future years?
6. How did you find the recent physics teachers' in-service day? What are your views on teacher development and support structures for physics teachers?
7. What are your views about
 - a) the teachers' role?
 - b) the learners?
 - c) the subject of physics?
 - d) assessment?
 - e) curriculum?
8. How were you taught physics when you were at school?
9. How has the new physics curriculum document affected your thinking about physics education, even if it has not changed your practice?
10. How have you changed as a physics teacher over the last five to ten years?

***APPENDIX D: Brief Summary by the Researcher of the Writing
Contracts***

Appendix D

The researcher's summary of the two Ministry contracts for writing *Physics in the New Zealand Curriculum*

There were two contracts for the writing of the new physics curriculum document. The first contract was for writing the draft of *Science in the New Zealand Curriculum (Physics)* as the document was seen as an extension of the *Science in the New Zealand Curriculum*. The name was changed in the second contract where the final document now called the *Physics in the New Zealand Curriculum* was to be drafted. The same three writers of the first contract won the right to work on the second contract.

The first contract was signed between the Ministry of Education and a College of Education in December 1992. The brief included a schedule of duties and the milestones to be met. The schedule of duties was detailed and encouraged the contractor to identify and take into account current issues and trends in physics education in New Zealand and overseas. The details included writing a rationale for physics education, approaches to teaching and learning physics, achievement aims, achievement objectives organised in three progressive levels (levels 6, 7 and 8). The achievement objectives needed to be tied in with the Essential skills in *The National Curriculum of New Zealand* discussion document. They needed to demonstrate progression and continuity in learning through the three levels, and needed to be specific enough to be assessed and to monitor the progress of students so as to provide information about each student's achievement. Further instructions to write sections on assessment examples, sample learning contexts, possible learning experiences within each of the three specified achievement levels that were consistent with the *Science in the New Zealand Curriculum* were included in the contract. There were also included injunctions to address advice given by the Ministry's group, set national guidelines for school physics, build on current understandings and best contemporary physics teaching practice and address barriers that prevent achievement. Advice in the contract was given on how to form the writing group and the writers' reference group – need for a balance of people with expertise in physics, teachers, people from research and industrial settings, views of Maori, women and girls to be considered. Four milestones were given for each draft from February 1993 to June 1993 to

produce the final draft for circulation nationally for comments and submissions. Details for each milestone was clearly spelt out. Each draft was subjected to guidance and recommendations of the Review Committee and the Project Reference Group (Physics)

The second contract was for writing the final document now called *Physics in the New Zealand Curriculum*. The same three writers were involved and the contract was again signed between Ministry of Education and a College of Education in April 1994. Similar schedule of duties were listed with the main duty to revise the draft Physics in the New Zealand Curriculum in accordance with the attached writing brief. There were three milestones to be met ranging from May 1994 to August 1994. The writers were expected to attend meetings with the Ministry's representative (Curriculum Facilitator) to discuss recommendations of the Policy Advisory Group, the Review Committee and the Project Reference Group (see Figure 4). At the final milestone, the writers had to submit two written copies, and a copy on disk, of the final draft (physics) to the Curriculum Facilitator.