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Professor Tony Brown's Inaugural Address
Special Section on Theorising Pedagogy

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ANALYSING PEDAGOGICAL CHANGE: PHYSICS TEACHERS' RESPONSES TO A NEW CURRICULUM

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ABSTRACT *This paper describes teachers' attempts to implement the 1994 New Zealand physics curriculum in the first year of its introduction to secondary schools in 1998. Analysis of interviews with 10 physics teachers and the three curriculum writers led to the identification of a number of barriers to changes in pedagogical practices. The barriers identified aligned with factors that had been identified by other researchers as important influences on teachers undergoing change. It is argued that a sociocultural perspective suggests that there were three main reasons why significant pedagogical change was not occasioned by the curriculum document. Firstly, there was very limited knowledge about why changes were being implemented. Secondly, there was little social and system support for the curriculum change. Finally, teachers had no time to focus on and reflect on the change.*

INTRODUCTION

This paper examines the challenge of effecting a pedagogical change through curriculum reform. It describes some of the issues that surfaced in a research project for a doctoral thesis (Fernandez, in progress) involving the curriculum writers and 10 New Zealand physics teachers who identified these issues as influencing their pedagogy when a new physics curriculum was introduced in 1994. The paper attempts to show that these issues are congruent with the factors set forth in several theories of teacher change. In particular, it evokes the argument of Fullan (1999) that theories of change of action need to be developed alongside theories of education by policy makers in order to carry out educational reform. Drawing on a sociocultural perspective, it then identifies three key elements that need to be aligned in the implementation of curriculum reform if intended pedagogical change is to occur.

THE CURRICULUM REFORMS

The backdrop to this study is the latest round of curriculum initiatives in New Zealand, which resulted in the first ever curriculum document to be written for senior physics in secondary schools in New Zealand. In the past, teachers had taught using the exam prescriptions as guidelines for the content of the physics courses at Years 11, 12 and 13.

The introduction of *The New Zealand Curriculum Framework* (Ministry of Education, 1993a) required documents for the different curriculum areas to be written. When the *Science in the New Zealand Curriculum* document (Ministry of Education, 1993b) was written, three separate curriculum documents for the senior school subjects of Biology, Chemistry and Physics were asked for by the then Minister of Education, Lockwood Smith. Three people were contracted to write the

physics document and, after the draft was published in 1993, submissions were received from teachers and other concerned parties. The feedback was used to produce the final physics curriculum document in 1994 and the mandated year of implementation was in 1998. In the meantime, union action over wage claims was taken in the form of a moratorium by the secondary teachers union, the Post Primary Teachers Association (PPTA), in 1996 that banned any work associated with the new curriculum framework.

The physics curriculum document (Ministry of Education, 1994) was divided into three levels corresponding to Years 11, 12, and 13 with three strands at each level based on theory, context/society and experimentation. There were achievement objectives for each strand at each level and specified content, compulsory and optional, as well as suggested learning contexts and learning experiences, and assessment examples. Investigation skills for each level were also identified.

INTERVIEWS WITH TEACHERS AND CURRICULUM WRITERS ABOUT IMPLEMENTATION

The research documented here is based upon face to face interviews with the three writers of the physics curriculum document in 1996, and 10 physics teachers in the years 1996 to 1998. (1997 was originally the year mandated for starting implementation of the new curriculum but the moratorium postponed the starting year to 1998.) The teachers' comments were collected from three interviews at different stages of the first year of implementation, one before the year of mandatory implementation in 1996, one during the first year of implementation, mid-1998, and one after the first year was completed, end of 1998. Also, documents were collected of their teaching and assessment schemes. The researcher also attended an in-service course run during the first year of implementation and has had access to documents and teaching schemes provided by the writers and the teachers.

The data code used in this article refers to comments by 10 teachers (Tr) labelled from A to M (excepting E, G, and I) in the three interviews, 1, 2 and 3; and the three writers (Wr) labelled 1, 2 and 3; for example, Wr2 refers to the second writer's comment, and TrA/2 refers to the teacher labelled A's comment in the second interview.

FROM DRAFT TO FINAL DOCUMENT

The major difference between the draft document and the final document for physics was the inclusion of compulsory topics in the specified list of contents at each level. This solved the problem of defining a progression of achievement objectives (that was initially attempted using different wordings in the description of the achievement objectives for the different levels in the draft). The suggestions for pedagogy were set out in one of the first few pages of the document in a section headed "Approaches to Teaching and Learning" (Ministry of Education, 1994, p. 7).

When interviewed, the writers of the curriculum document were keen to emphasise that they did not make any major changes to the topics covered in the courses but the main thrust of the reform was in effecting a change in the way physics was taught in the classrooms:

...Physics hasn't changed; it is just the way you are presenting it to students that is going to have to change ... there is a basic core of physics ... we didn't want to change it too much because our aim was to change the approach ... (Wr2)

However, the achievement objectives of the senior physics curriculum extended the focus from dwelling on the learning of concepts and doing standard experiments to incorporating the nature of physics knowledge and the impact of physics on society including ethical and environmental concerns. This widening of the physics curriculum implied embedding the traditional teaching of concepts and experimentation more in real world situations:

Those statements actually change the nature of the physics curriculum from what has existed in this country prior to that document, I suppose. There was no legislated document to take into account the human face of physics, to relate physics to society in any sort of way. (Wr3)

The writers of the curriculum document were coming from a constructivist background and wanted the physics curriculum to incorporate a constructivist view of learning that acknowledges learners' prior knowledge and that takes into account students' thinking in the way it is taught:

I see the three of us were constructivists in the sense that we are interested in how the kids are learning. ...Our ideal idea of teaching is very interactive with kids and puzzling over things... (Wr1)

...teaching programmes acknowledge that students bring into 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; ... (Ministry of Education, 1994, p. 7)

The main changes that they highlighted in the curriculum document were the societal aspects of physics, the nature of physics knowledge, having open-ended investigations and starting from the real world situations as contexts for learning. There was an exploratory, hands-on emphasis in the suggestions given in the curriculum document, encouraging greater involvement of students in their own learning:

...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 and obscure; it is 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 it is not recipe experiments all the time, which physics is generally known for. ...So we were trying to inject some kind of life into the physics curriculum...[so that] they [students] have an affection for physics. (Wr1)

While the curriculum document suggested a need for change in the way physics was traditionally taught, a number of the physics teachers who were interviewed described themselves as still being traditional physics teachers. Their pedagogy involved some demonstration, transmission methods of teaching the concepts, standard physics experiments that they have prepared equipment for, and solution of numerical problems that were expected to be encountered in the examinations:

...quite a lot of chalk and talk, a lot of questioning, overhead projector use, notes, diagrams, working through workbooks...a lot of demonstrations and practicals...I am probably more traditional than perhaps the newer breed of teachers. I don't use a lot of discussion, well I do discussion, I do a lot of talking and listening, telling stories, giving examples, but in terms of debates, debating issues, no, I don't do that. ...I still see myself as someone who directs the kids, you know a bit of chalk and talk, writing up notes... (TrB/1)

These teachers' descriptions fit the traditional curriculum described by Elliot (1998) as "a transmission mode of teaching...involving a form of communication that establishes the teacher's control over the content and process of learning" (p. 133).

REASONS UNDERLYING A LACK OF PEDAGOGICAL CHANGE

Despite comments from the writers of the physics curriculum document 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 rewrite and submit their new teaching schemes to the Ministry of Education based on the new curriculum. Fernandez (in progress) has identified 20 reasons from the accounts given by the writers and the teachers for this lack of pedagogical change. They are listed below.

1. The Lack of Guidelines and Clarity

The writers despaired about the lack of a follow up document that was meant to have been written as a guideline to the original document. In the interviews, the writers 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 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 [sic] 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. (Wr1)

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. (TrH/1)

2. The Curriculum Document was Confusingly Eclectic

a) The writers wanted to introduce teaching based upon constructivist ideas of learning but did not identify constructivism as the source of their ideas. Contexts were suggested that implied contextual teaching approaches, some content was listed as compulsory and other content as optional, historical and philosophical ideas were incorporated, societal and environmental issues were included. So there was a range of underlying principles 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, just go through the content areas, and so we thought that that gave them flexibility. (Wr2)

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 Curriculum Framework (Ministry of Education 1993a) 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 objectives 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 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. ...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. (Wr1)

3. The Curriculum Document Was Not Radical Enough

The writers wanted to encourage change but had a sense that they could not be too radical so as to turn teachers away. However, the familiarity of much of the content in the document encouraged teachers to remain with their existing practices:

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. (W1)

4. The Prescribed Content Distracted 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 focussed on the achievement objectives and not the topics to be covered. As most of the compulsory topics appeared unchanged, this caused the physics teachers to focus once more on topics to be taught rather than widening the scope of physics which was conveyed more 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]. (TrB/1)

5. Teachers' Pedagogical Content Views on the Nature of Physics Were at Variance with Suggestions in the Document

School physics was mainly seen by some of the teachers as having a core body of knowledge that needed to be understood by the students before they could 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 got here is facts and that it's absolute. ...We confuse people with ifs and buts. (TrD/3)

6. 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. The new directions in the curriculum document would involve them in exploring a pedagogical change that would take them outside their comfort zones. This can be risky and stressful especially since they can become more prone to criticism. New approaches may also mean that confident expert teachers may be reduced to becoming 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. (TrK/3)

7. 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. (TrA/2)

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. (TrL/2)

8. 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 relationship between the professional developers (e.g., science advisers) and classroom teachers being a case of 'the 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. (Wr1)

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]. (TrM/2)

9. Delay Due to a Moratorium

A moratorium placed on the entire process of curriculum reform by the Post Primary Teachers Association (PPTA) due to wage negotiations meant that for some physics teachers there was a lack of urgency and they delayed exploring the new physics curriculum. The in-service courses were careful not to breach the moratorium and so the professional development on the new curriculum was stifled and half-hearted:

Last year 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. (TrJ/2)

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. (TrA/1)

10. The Lack of Trialling of the New Physics Curriculum

A serious setback for the successful implementation of the physics curriculum document was seen by both writers and teachers as 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. (Wr2)

11. The 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 the achievement objective of the nature of physics and societal issues was seen as a diversion from the "real" physics, and contextual methods were seen as inappropriate, being time consuming and inefficient in 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. (TrA/1)

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. (TrF/1)

12. The Existence of a Sample Teaching Scheme that Upheld the Status Quo

A sample scheme of work for senior physics designed by a group of South Island teachers was presented to Hamilton physics teachers at an in-service course on unit standards. Some of the teachers who were interviewed saw it as a confirmation that they were already fulfilling the new curriculum with their current practice. Obviously 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 because I felt that the scheme I had already was enough, using this 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. (TrA/2)

13. "We are 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. (TrC/3)

14. Amount of Change Required Was Too Much for Some Teachers

The starting point for change was different for the different teachers as some were already teaching in ways congruent with 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 may be too big or too difficult for some teachers to manage whereas for others the new ideas may be aligned with their existing philosophies. Furthermore, the required change may not be acceptable to the teacher:

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. (TrF/1)

15. Being Contented 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. (TrA/2)

16. 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 is 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. (TrL/3)

New assessment initiatives in terms of unit standards (New Zealand Qualifications Authority, 1992) 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. (Wr1)

17. Students' Needs Militated Against Pedagogical Change

Some teachers felt that their first obligation was to their students and their needs. In senior physics, exams and qualifications are important, so these teachers were only willing to change if that was helped in any way. Other needs and expectations of the students were taken into consideration as well:

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. (TrH/2)

18. Change Occurs Gradually

The teachers were interviewed only in their first official year of implementation of the change. Some teachers indicated that further implementation of the new curriculum was 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. (TrM/3)

19. 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, electronics, or mathematics. Furthermore, assessment changes in terms of unit standards were being introduced at the same time (NZQA, 1992):

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. (TrK/1)

20. The Lack of 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 were still admitting that they had not looked at the curriculum document thoroughly. However the writers have pointed out that time to read and think were crucial to understanding the document:

So when a teacher looks at this, 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. (Wr1)

I think the major need is time out to have a jolly good think about it without all the constraints from day to day teaching. ...You need uninterrupted time to think about it. (TrB/1)

b) Time was also seen as a constraint for not using some of the recommendations 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. (TrD/2)

In summary, about seven of the 10 teachers who were interviewed felt that they did not make major changes in their pedagogy and, as such, did not move to the position suggested in the curriculum document. This outcome 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.

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 things got cut off. So that's sad really, 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. (Wr2)

The lack of change does not imply that the curriculum was perceived as uniformly unfavourable. 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 ideas 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. There were two teachers who appeared to understand well the new ideas in the curriculum document and the common factor between them was that they 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 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 to satisfy the new curriculum.

The reasons for teachers' lack of change listed above are the propositions that emerged from the interview data. These propositions have to be tested and related to other theories. In particular it is necessary to find deeper levels of theoretical meaning that can account for the propositions and data of the study. In order to develop such a theoretical account of the factors underlying the (lack of) pedagogical change during the implementation of New Zealand physics curriculum, we carried out two analytic steps. Firstly, we related the reasons mentioned by teachers to the teacher change factors identified in extant research and theory. Secondly, we interpreted the most important factors underlying teacher change within a sociocultural theoretical framework often used to theorise the social basis of knowledge and learning. The section that follows describes the first of these analytic steps. The final section of this paper describes our sociocultural explanation for the lack of pedagogical change amongst the teachers in our study who were implementing the physics curriculum.

RELATIONSHIP OF EMERGENT ISSUES TO THEORIES IDENTIFYING FACTORS IN TEACHER CHANGE

Existing literature was explored to review the issues involved in teachers changing their pedagogy. A number of writers and researchers including Bell and Gilbert (1996), 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. Distilling the common threads running through these studies, Fernandez (in progress) identified seven factors which appeared influential in enabling teachers to change. These are expanded below with views from other writers that support these factors.

1. 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; the existing program is already considered successful (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 seem 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.

2. Beliefs About Educational Issues and the Change (Includes Professional Judgment)

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, 1985).

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

identity can be challenged by any incoming curriculum change (cf. Goodson, 1987).

3. Clarity of the Change

Teachers need to be clear about what the change is about. Knowing what the change is and how it is to be carried out, as well as why the change is being made, will enable them to change. Too often, teachers are expected to implement changes without any understanding of 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).

4. 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 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).

5. Supports / Barriers for 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 attempting change. 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). It has also been identified as important for teachers attempting change (Fernandez, 1994; Fullan, 1991; Hargreaves, 1994; McGee, 1997).

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

6. Personal Costs to the Teacher and the Possible Benefits

The personal cost to the teacher when trying something new includes 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. Other personal costs involve the amount of time and energy required to be expended in implementing the change.

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.

7. Personal Disposition Toward Change

Personal disposition includes the teachers' personalities, their background experiences and their career stages, 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 teachers' dispositions towards their work and change (Hargreaves, 1994). Background experiences of teachers give rise to beliefs that are quite resilient to change despite 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' dispositions 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 and mandated.

The seven factors identified above can be seen as overarching the issues that emerged from the study of the implementation of the physics curriculum. Table 1 provides a schema which shows how these factors connect to the issues in the current study. The correspondence between the issues emergent in the study and the factors in the list demonstrate the usefulness of the latter in illuminating key dimensions that need to be considered when striving for an educational change.

The comments of the 10 teachers in the first year of implementation of the physics curriculum indicated that for many of them little change in their pedagogy had occurred. Given the negative direction of the teachers' comments with respect to the seven change factors above, the lack of pedagogical change by the teachers in the current study could have been predicted. Thus, the list in Table 1 is useful for highlighting the factors influencing pedagogical change which need to be attended to by curriculum developers if a change is to be enabled.

TOWARDS A SOCIOCULTURAL UNDERSTANDING OF PEDAGOGICAL CHANGE

The qualitative categories or factors listed above are fundamentally descriptive and although 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. An explanation from a sociocultural perspective can provide insights into the process of pedagogical change and give an account of the essential nature of such change. At this level, the proposed change in pedagogy would have demanded a cultural shift with regards to what it means to be a teacher of physics, involving a "renegotiation and reconstruction of what it means to be a teacher..." (Bell & Gilbert, 1996, p. 13).

Table 1. Factors Identified in the Literature Related to the Issues Emerging from Interviews with Teachers.

<i>Factors Identified in Literature</i>	<i>Issues Emerging from Interviews</i>
1. Need for change	4. Inclusion of prescribed content in the final document 13. "We are already doing it" 15. Contented with existing practice
2. Beliefs about educational issues and the change (includes professional judgement)	5. Teachers' pedagogical content views about physics 11. Unsuitability of suggested ideas 17. Student needs as first priority
3. Clarity of the change	1. Lack of guidelines and clarity 2. Document was eclectic
4. Practicality of the change in the school situation	10. Lack of trialling 16. External exams and assessment initiatives 18. Change is a gradual process 19. Too many changes at the same time 20. Lack of time
5. Supports / barriers for the change	7. Professional development was not well coordinated (lack of support) 8. Lack of communication with writers (lack of support) 9. Moratorium (barrier) 12. Having a sample scheme (barrier)
6. Personal costs to the teacher and the possible benefits	3. Document not radical enough 6. Teachers may need to move out of their zones of expertise
7. Personal disposition toward change	14. Amount of change required may be too much

Conceptions about the nature of science, about the goals and purposes of teaching physics, and about teaching and learning of physics were identified by Fischler (1994) as important variables that impact on the thinking and acting of physics teachers. If these conceptions are at variance with the proposed views in the new document, 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 & 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 the professional development provided. Does the professional development enable teachers to grapple with issues such as those in the paragraph above in relation to a new curriculum? At the in-service course

that was attended by Teresa Fernandez, the physics teachers were interested mostly in **what** the changes were; 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 at all about the philosophy of the changes or the underlying ideas and beliefs; in other words, 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.

Bell and Gilbert (1996) also suggest that professional development needs to go beyond the "what" and "how" and address the "why" questions about the change: "Professional development...involves not only the use of different teaching activities but also the development of the beliefs and conceptions underlying the activities"(p. 13).

The process of the curriculum development, the theories that underlie the change and the arguments that were 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, a reconciliation of the two if divergent or even a rejection of the new ideas if found unacceptable.

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 were 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)

In the present context of a curriculum change, the artifact (or technology) is the curriculum document. The lack of communication between those in the design process and those involved with the implementation of the curriculum forms a screen that denies teachers access to a greater understanding of the document and the change involved. Teacher access is not just in using the document but also in understanding the underlying issues forming the basis of the document. This access will enable the teacher to become autonomous with respect to the change and its meaning and lead to better informed participation.

Kennedy (1986) also suggested that greater understanding could be achieved when the screen between design and implementation of new curricula was removed:

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)

Teachers are curriculum developers whether they come in at the beginning or at the end of the official process of the curriculum development because essentially they develop the curriculum for their classrooms. Handing them a very detailed curriculum, or sample scheme, only satisfies their immediate needs. There are deeper, underlying needs that have to be addressed so as to sustain a change by giving teachers access to the process and issues in the design of the document.

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 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 about it. There is the need for networking and support structures among teachers as they explore the change. As Bell and Gilbert (1996) pointed out in their study, "Giving and receiving support facilitated professional, personal and social development" (p. 104). Keiny (1994) identified reflection on classroom practice in social contexts as 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" (Keiny, 1994, p. 244).

Furthermore, 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, and expectations of students, school, parents and even the wider community must in some ways be in line with, or at least adaptable to, the proposed changes.

The example of Teacher K illustrates this. 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 hard to remain with his new ideas because of the constraints and parental expectations of his new school. It is also illustrated in the case of Teacher D who was quite a progressive teacher but he 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.

Further networking within the school and with the outside community will be necessary to ensure that conditions and structures support, or at least are adaptable to, the changes being suggested (cf. political force in Fullan, 1999).

Finally 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 (cf. Hargreaves, 1994).

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 how and why of the curriculum change corresponds to a lack of cultural capital. Lack of professional development opportunities to break through isolation and connect with other teachers corresponds to a lack of social capital. Finally a lack of time to study the document and work out new ways of practice corresponds to a lack of economic capital invested into teachers. From the perspective deriving from Bourdieu's theory, the government, while being instigators of curriculum reform in this research, did not

ensure that there was 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). 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) will enable teachers to become key players in educational change. These factors can be linked to the three key elements of knowledge, support and time required for a profound change as suggested in this article.

Thus theories of pedagogical change are necessary to fully comprehend the reality of educational practices. Changes are inevitable; 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. Bayliss (1998) has pointed out that "If we are dealing with complexity, we (as practitioners and researchers) must accept that change, mutability and non-predictability are natural parts of dynamic systems and that 'certainty' is only provided by an artificial view of the world" (p. 78).

In summary, we 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: The 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 had to make sense of the document on their own with little professional development on the new curriculum; and

b) adaptability of systems and structures to the change: For example, assessment procedures that are not adaptable to the suggested curriculum can undermine its implementation.

3. Time. Time out to focus on the change: Even after six years of the new curriculum document being out, some physics teachers have still not read it in full.

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. A theory of pedagogy that extends into pedagogical change will highlight the need for teachers to nurture the capacity to change, while reflecting on the basis of their current pedagogy.

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