

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**BRIDGING THE GAP BETWEEN  
THEORY AND PRACTICE**

**What impact do the national curriculum exemplars  
and the associated matrix have on teaching and learning in  
science?**

**A thesis submitted in partial fulfilment of the  
requirements for the degree of  
Master of Education  
at  
Massey University**

**Anne Grace Radford  
2006**

## **Abstract**

Formative assessment continues to be influential in shaping teaching and learning. A National Assessment Tool, the Exemplars and associated Matrix have been designed and provided for teachers to support formative assessment practice. While considerable research exists on formative assessment, the impact of the exemplars and matrix on teaching and learning in science is unknown, therefore this Participatory Action Research study explores the impact on teaching and learning, assessment and the resultant teacher–student interactions in science learning.

Two schools were involved in the action research project in 2004. Seven teachers participated in the research study. The students ranged in age from five to nine years. Through in-depth classroom observations, planned interventions and semi-structured interviews, two major themes emerged: the teacher participants' science knowledge and pedagogy; and, their formative assessment practice and knowledge. Two sub-themes emerged and impacted on the major themes: the 'teacher as a learner', and the research/professional development model.

The matrix and exemplars were the vehicles for change and the findings of this research study, clearly show evidence of improvement to teaching and learning in science.

## Acknowledgements

To the wonderful teachers I worked with, thank you. You are indeed inspirational and a joy to work and learn with.

Thank you to my family and friends for your patience, support and I hope continuing friendship, as I became less and less hospitable and communicative. Graeme, I have appreciated your tolerance and care. The changes to your life have been many.

To Mike W, you were so instrumental in starting me on this pathway. Your unfailing kindness, and your innate understanding and ability to develop 'talents' in others, are truly gifts.

To my colleagues who have had to listen to me 'going on', I have so valued your forbearance, your expertise and the discussions we have had.

To my supervisor, Doctor Jenny Poskitt, you are the master of formative assessment. Without you I would never have completed this Thesis. Your interest, encouragement and expertise meant everything. Thank you.

*Hold fast to dreams for if dreams die*

*Life is a broken winged bird*

*That cannot fly*

Langston Hughes

## Table of Contents

<b>Abstract</b> .....	ii
<b>Acknowledgements</b> .....	iii
<b>Table of Contents</b> .....	iv

### CHAPTER 1: Introduction

The exemplars and associated matrix.....	2
The research problem .....	3
The research question.....	4
The participating schools.....	5
Emergent themes .....	5
Organisation of the thesis.....	6

### CHAPTER 2: Literature Review

Introduction.....	8
What is understood by science teaching and learning? .....	9
What is understood by formative assessment? .....	13
Putting the theory into practice: Science pedagogy.....	16
What factors interact with teacher change?	
The professional development model .....	19
Teacher as a learner .....	22
Understanding the National Science Exemplars and Matrix.....	24
Contradictions, gaps and contributions in current research.....	26
Chapter summary.....	27

### CHAPTER 3: Methodology

Introduction.....	29
Theoretical underpinnings	
Action research.....	29
Participatory action research.....	32
Participatory action research and professional development.....	34

Research study .....	35
Structure of the study	
Research population.....	36
Action research cycle .....	38
Timetable.....	38
Planning for action.....	38
Observations .....	39
Interventions .....	39
Interview .....	41
Data gathering tools .....	41
Document analysis .....	47
Transcript analysis.....	47
Ethical considerations.....	48
Issues and difficulties .....	50
Chapter Summary .....	52

## CHAPTER 4: Findings

Introduction.....	53
Organisation of data .....	54
Themes to emerge .....	55
Cycle One:	
1A Planning for action .....	56
1B Observation of teacher participants .....	58
1C Intervention .....	62
1D Reflection: Interviews.....	65
Summary of cycle one .....	68
Cycle Two:	
2A Planning for action .....	69
2B Observation of teacher participants .....	70
2C Intervention .....	73
2D Reflection: Interviews.....	74
Summary of cycle two .....	77
Cycle Three:	
3A Planning for action .....	77
3B Observation of teacher participants .....	78
3C Intervention .....	81
3D Reflection: Interviews.....	82
Summary of cycle three.....	85

Cycle Four:	
4A Planning for action .....	86
4B Observation of teacher participants .....	86
4C Intervention .....	89
4D Reflection: Interviews .....	90
Summary of cycle four .....	93
Chapter summary .....	94

## CHAPTER 5: Discussion

Introduction.....	95
Science teaching and learning: Putting the theory into practice	
Co-constructivism .....	96
Discourse.....	100
Questioning .....	100
Planning.....	101
Children investigating .....	102
Interacting with the exemplars and matrix	
The matrix.....	103
The exemplars.....	106
Considering teacher change.....	108
Major themes to emerge	
Teachers' knowledge of science .....	108
Teachers' formative assessment practice .....	109
Progression in learning.....	110
Sub-themes to emerge	
The action research/professional development model.....	110
Teacher as a learner .....	113
Chapter Summary .....	114

## CHAPTER 6: Conclusion

Introduction.....	116
Factors to consider when using and implementing the	
National exemplars and matrix .....	116
Methodology selected .....	120
Triangulation.....	120
Limitations of the research .....	121

Contribution to the literature .....	121
Recommendations for further research .....	122
Chapter summary .....	123

<b>References</b> .....	125
-------------------------	-----

## **Appendices**

Appendix 1	Exemplars and matrix
Appendix 2	Examples of field notes
Appendix 3	Core questions asked in interviews
Appendix 4	Examples of transcript analysis
Appendix 5	Information letters
Appendix 6	Collation of interview data
Appendix 7	Planning format sample

## **List of Tables**

Table 1	Emerg ed themes .....	6
Table 2	Organisation of data .....	54

# **BRIDGING THE GAP BETWEEN THEORY AND PRACTICE**

**What impact do the national curriculum exemplars and the associated matrix have on teaching and learning in science?**

## **CHAPTER 1: Introduction**

This Participatory Action Research study is an investigation into the impact of the National Science Exemplars and associated Matrix on science teaching and learning. It aims to explore the impact on teaching and learning, assessment and the resultant teacher–student interactions in science learning. The impact of the exemplars and matrix on teaching and learning in science is unknown and has therefore led to this research.

A Ministry of Education research project (Poskitt, 2002), has followed the development and the early implementation of the exemplars and the effects of the exemplars on teaching and learning within curriculum areas. However, the national research study did not look at individual teacher development and use of the exemplars over time, which was the aim of this project. The present research will inform the researcher's practice and understanding as a science advisor and an assessment facilitator in the Ministry of Education Assessment for Learning project. Knowledge gained about the procedures and issues confronting teachers in using the National Exemplars and the Matrix will help shape future professional development in Science.

### **The exemplars and the associated matrix**

The development of the National Curriculum Exemplars as a key component of the *National Assessment Strategy* (Ministry of Education, 2000) provided an alternative to National Testing of students at stages during their primary and intermediate schooling.

With recent research and thinking in assessment (such as Crooks, 1988; Sadler, 1989; Gipps, 1999; Clarke, 2001; Black, & Wiliam, 2002; Clarke, Timperly and Hattie, 2003), changes in the purpose of assessment occurred. Assessment 'for' learning, that is formative assessment, became more preferable to assessment 'of' learning, or summative assessment. Interest in national testing waned in favour of exemplar development, which would provide schools with a tool to moderate their own performance against a national standard and provide teachers and students with criteria and indicators of progression<sup>1</sup> to support their learning within specific curriculum areas.

According to the Ministry of Education (2002, p. 1) an exemplar is an "authentic example of student work annotated to illustrate learning, achievement, and quality in relation to the levels described in the national curriculum statement. Each exemplar highlights significant features of that work and important aspects of students' learning". Exemplars have been developed in each of the seven curriculum areas: English, mathematics, science, technology, social studies, health and physical well-being and the arts. The exemplars have also been developed in the equivalent Maori-medium curriculum areas. Features of the exemplars (see Appendix 1) are:

- Examples of student work both, in an annotated and unannotated form. Annotated samples of work demonstrate appropriate criteria and achievement.
- Links to the national curriculum document, and learning outcomes and teaching sequence according to a curriculum level.

---

<sup>1</sup> Progression: refers to significant changes in knowledge, skills, processes and concepts across time.

- 'Where to next', the next learning and teaching steps for students and teachers.
- Teacher-pupil interactions, which provide a model for eliciting what the children think and how their learning could be extended.

The associated matrices are a rubric-type framework, which specify key aspects of the particular curriculum area, and identify progress indicators for each of these aspects from novice (level 1) to expert (level 5). The progress indicators link closely to the annotations on the exemplars. The matrix has been divided into four categories or matrices of science:

- Developing interest and relating science learning to the wider world,
- Investigating in science,
- Thinking in scientific ways,
- Developing and communicating science understanding.

In each of the matrices the key aspects and progress indicators provide an insight into the nature of science, and teaching and learning in science. The matrices are linked to the contextual and integrating strands and the levels of the National Science Curriculum.

### **The research problem**

Effective and appropriate formative assessment is increasingly being recognised as playing a crucial role in the enhancement of learning. Sadler (1987) and Gipps (1999) argue that the use of 'concrete models' and frameworks (the exemplars and matrix) will enhance teaching and learning, and Gipps (1999) declares that exemplars can be used to explicate to teachers the nature of the skills being taught. As a result teachers' content knowledge can be developed. The aims of this research are to investigate the reality of these claims, in the absence of supporting research, and to explore the role of the exemplars and matrix in teaching and learning in science.

### **The research question**

Therefore the overarching research question is:

*What impact do the national curriculum exemplars and the associated matrix have on teaching and learning in science?*

Implicit within the overarching question are several sub-questions. These were asked of the teacher participants in order to elicit their ideas and thinking about the National Exemplars and associated Matrix and, especially, to generate discussion:

- In what ways do teachers interact with the exemplars and matrix?
- What are the changes on teaching and learning in science, if any, resulting from the interaction with the science matrix and exemplars?
- What factors have contributed to changes in teaching and learning in science?
- What are the outcomes for students and teachers?

To answer these questions, a Participatory Action Research (hereafter referred to as PAR) approach was chosen as it is underpinned by principles held by both action research and effective professional development. Such an approach focuses on problems that are of immediate concern to the practitioners, develops reflective practitioners, is a collaborative activity, is undertaken 'in situ', improves the congruence between theory and practice, is dialogical and celebrates discourse, is participatory, and changes the competencies of practitioners (Hult & Lennung, 1980, cited in Cohen, Manion & Morrison, 2000; Noftke & Zeichner, 1987, cited in Cohen et al., 2000).

### **The participating schools**

Two schools were involved in the action research project in 2004. School A, an urban decile<sup>2</sup> four, full primary school (years 1-8) with a roll of 300 students; and School B, an inner city decile seven primary (years 1-6) school, of 350 children. Both schools had requested on-going adviser support with science or assessment. One syndicate from each of the schools, seven teachers in total, participated in the research study. The students ranged in age from five to nine years. Further detail is provided in Chapter Three.

### **Emergent themes**

Data from each of the sources were aggregated into categories from which two major themes emerged as the teacher participants engaged with the exemplars and matrix. The major themes: the teachers' confused assessment practice (that is, the notions of progression in science and formative assessment practices); and the teachers' knowledge of science (that is, the nature of science, science conceptual knowledge, and science pedagogy). As the teachers participated in the PAR and worked with the exemplars and matrix, two sub-themes were revealed: the 'teachers as learners', and the nature of the PAR and the professional development model. The sub-themes influenced the way the teachers participated in the action research and the way in which they interacted with the matrix and exemplars. More detail about the sub-themes is provided in Chapters Four and Five.

---

<sup>2</sup> Decile: the ranking system for all New Zealand schools on a scale of one to ten. It is a measure of socio-economic position, with one being the lowest ranking and ten the highest. Some school funding is allocated on the basis of decile ranking.

<b>Table 1: Emerged Themes</b>	
Major Themes/Problems	
The teachers' assessment practice <ul style="list-style-type: none"> <li>• formative assessment practices</li> <li>• progression in science</li> </ul>	The teachers' knowledge of science <ul style="list-style-type: none"> <li>• the nature of science</li> <li>• science conceptual knowledge</li> <li>• science pedagogy</li> </ul>
Sub Themes	
The participants as 'teachers as learners'	The nature of the PAR / PD Model

### **Organisation of the thesis**

Chapter One introduces the research study. The purpose for the research, the research question, and the National Exemplars and Matrix assessment tool is described. A brief description of the research population and the themes to emerge are provided.

Chapter Two reviews the literature. Current theories of teaching and learning in science, and formative assessment are discussed. The purpose and benefits of assessment tools, such as the National Exemplars and associated Matrix are documented in the current literature about assessment.

Chapter Three examines the methodology used and discusses the theoretical basis for the researcher's choice of Participatory Action Research. It provides justification for the data collection and analysis techniques employed, and explains the practical aspects of the chosen methodology and techniques.

Chapter Four presents the main body of the findings as the emergent themes are revealed and developed. The themes are justified through the triangulation of data from the various sources, observations, interviews, discussions and documents. Data and extracts, presented to support the researcher's claims, are collated according to the research cycles, and then

further organised according to the phases of Action Research; planning for action, observation, intervention and reflection.

Chapter Five links the findings and the literature to identify the changes to teaching and learning in science and the issues and factors that impact on the changes, as a result of the teacher participants interacting with the National Science Exemplars and Matrix.

Chapter Six draws the research to a close. Key findings from the Action Research study and the contribution that this research study could make to the literature are discussed. Brief discussion and comments on the validation of the research model, are followed by the limitations of the study and future research recommendations are provided.

## CHAPTER 2: Literature Review

### Introduction

*Standards can be specified through a combination of descriptions and exemplars.*

(Sadler, 1987)

*“Exemplars can be used to explicate to teachers the nature of the skills being taught and as a result teachers’ content knowledge can be developed”.*

(Gipps, 1999, p. 160)

The purpose and benefits of assessment tools, such as the National Exemplars and associated Matrix (see Appendix 1), that specify evaluative criteria and appropriate standards are documented in the current literature about assessment. There is however, little research to support and illuminate these assertions. It is the intention of this Action Research study to contribute to the literature on the impact of such assessment tools.

In ascertaining the impact of the exemplars and associated matrix on teaching and learning in science, it was necessary to identify key aspects of teaching and learning in science and the nature and purpose of assessment. This Action Research study took place within a professional development context and therefore literature about professional development and factors that interact with ‘teacher change’ are reviewed.

This chapter then, will firstly consider the literature on science teaching and learning, followed by the literature on formative assessment. Science pedagogy is explored, as are the factors which impact on teacher change, the teacher as a learner and the professional development model. The chapter concludes by discussing the purposes of the National Exemplars and associated Matrix, the gaps in the literature, and the contribution this research could make to the literature.

### **What is understood by science teaching and learning?**

The understanding of science content and the teaching of it, has been embedded in constructivist theory. Radical constructivism is currently the leading theoretical position of constructivism. Von Glaserfeld (1990) introduced the term 'radical' constructivism to contrast with constructivism, the latter being predominantly built on the importance of prior knowledge and consequently referred to as weak or trivial constructivism.

The first principle of radical constructivism holds that knowledge is not received passively but is built up by the cognising subject. In other words, students' heads are not empty vessels to be filled with knowledge; rather they construct their own meaning from words and visual images. When engaging in this construction of meaning, what the learner already knows is of paramount importance. As a result, there is a critical need to ascertain students' prior knowledge before beginning a science unit of work.

Conversely Asoko (2002) asserts that there is little need for teachers to ascertain students' prior knowledge as much research (Osborne & Freyberg, 1985; Driver, Guesne & Tiberghien, 1992, cited in Shepardson, 1997) has identified the misconceptions students' hold about given science concepts. To learn science from a constructivist philosophy implies direct experience with science as a process of knowledge generation in which prior knowledge is "elaborated and changed on the basis of fresh meanings negotiated with peers and teachers" (Watts, 1994, p. 51). Teachers need then to focus on students' learning with understanding, rather than with the more recent emphasis on coverage of the curriculum.

The second principle of radical constructivism states that the function of the cognition is adaptive and enables the learner to construct viable explanations for experiences. Consequently knowledge about the world outside is viewed as a human construction. A reality outside is not denied, but it is only possible to know about the reality in a personal or subjective way. Constructivism then is concerned with the way in which learners construct viable and useful knowledge. The only constructions that survive are those that prove to be

successful in dealing with the multiple contexts in which the learner is engaged. Knowledge is not only personally constructed but is also socially mediated (Prawat, 1993, cited in Ritchie; 1998 & Taylor, 1993, cited in Treagust et al., 1996). Therefore the process of constructing meaning is always embedded within the social setting of which the individual is part.

Osborne's and Freyberg's (1985) research has shown that in relation to ideas taught in science, children from a young age develop their own meanings for words and their views of the world. These views are strongly held and are often different from the views of their teachers and the views of scientists. Treagust, Duit and Fraser (1996) assert that children often hold two inconsistent approaches to understanding science concepts, one intuitive and one formal. Children view their intuitive ideas as being sensible and coherent and often remain uninfluenced by science teaching. Students and teachers may also hold a passive view that conceptualised learning is the transfer of canonical knowledge (Treagust et al., 1996) to memory. In which case science knowledge is viewed as an accumulation of facts, not as constructing learning.

Constructivist teaching helps students develop constructions that lead to understanding of the scientific view. It is absurd to expect that students will be able to construct science conceptions, without any guidance, on the basis of pre-existing conceptions alone. Increasingly, constructivist writing has recognised the importance of discussion, not only student to student, but also with scientifically knowledgeable adults, as a means of enabling this construction (Solomon, 1994). Sutton (1992, cited by Sprod, 1998) maintains that practical experience itself does not bring about learning until it is animated by ideas, and these ideas are carried into words. It is critical to provide children with the opportunity to articulate their ideas so that they can understand their understanding, that is, become aware that their ideas are not the scientist's views. Without the opportunity for social discourse their ideas will not be challenged and moderated. Lawson (1990), cited in Lawson & Weser, 1990, argues that discourse improves thinking and develops reasoning skills, and reflective reasoners are more likely to change conceptions under instruction. Open discourse also allows students to assign language to their ideas and to

experience learning as a co-participatory activity (Tobin, 1997, cited in Dawson & Taylor, 1998). In so doing, students have the opportunity to experience science as a discursive activity in which value-laden knowledge claims are legitimised in accordance with canonical standards (Lemke, 1995, cited in Dawson & Taylor 1998; Roth, 1997, cited in Dawson & Taylor, 1998; Murphy & McCormick, 1997).

Constructivist theory asserts that learners develop ideas and beliefs about the world before they receive formal instruction. Learners do not store concepts in isolated bits; they form relationships or connections between concepts to form propositions (Novak, Mintzes & Wandersee, 2000). Meaningful learning takes place when the learner seeks to relate new concepts and propositions to relevant existing concepts in their cognitive structure. The learner must be actively involved in resolving contradictions, gaps and disturbances that arise when new information is juxtaposed with mental structures. Therefore students experiencing the same situation and information will each construct divergent conceptions depending on their varied prior experiences and existing knowledge (Novak et al., 2000). As a consequence, students' alternative conceptions may influence learning experiences in unpredictable ways if the teacher is unaware of them (Hewson, 1991, cited in Stahly, Krockover & Shepardson, 1999). Not only does investigating students' conceptions reveal important insight into the students' ways of thinking and understanding, it also helps teachers revise and develop their own knowledge and may lead to reconstruction of that knowledge. Awareness of students' conceptions can also inform the most appropriate way to present information. It is the similarities and the differences between students' science and scientists' science that are of central importance to the teaching and learning in science.

Harlen (2000) raises several notions about the teaching and learning of science and the influence of teachers' understandings on the way they teach science. She claims that teachers' views of the nature of science are implicit in all decisions they make and influence the extent to which students learn through *inquiry* or learn *about* science and its findings. She furthers this argument by stating that if teachers see learning in science as being essentially the receiving

and mastering of information, then teaching will be organized in such a way as to cause this, rather than students developing understanding for themselves. Carr, Barker, Bell, Biddulph, Jones, Pearson and Symington (1994) assert many teachers view science knowledge as being unproblematic, science as providing the right answers, that truths in science are discovered by observing and experimenting, and that choices between correct and incorrect interpretations of the world are based on commonsense responses to objective data. Teachers' understanding of the nature of science is therefore critical to the quality of teaching and learning in science.

Watts (1994) claims that constructivism implies a metacognitive position, which takes two forms. For teachers it is reflection and for students it is learning about learning. In science teaching and learning, emphasis is placed on active learners constructing and reconstructing their ideas. Taking responsibility for their own learning in ways they know they can, and being self determining within a social and caring learning community where ideas are communicated, shared, tested, negotiated and reported towards purposive ends. Constructivist teaching strategies need to encourage declaration about existing ideas and then promote consideration of whether other ideas make more sense. Contexts of learning influence the way in which individuals construct meaning.

Gipps (1999) asserts that current understanding of the cognitive processes indicates that there is an intimate connection between skills and knowledge and the context in which they are taught. Skill components cannot be taught in one situation with the expectation that they will be applied automatically to another. Rogoff and Lave (1986, cited in Hennessey, 1993; Murphy & McCormick, 1997) posit thinking is not only context based but also situation specific. Learning that relies on rote or recall learning conceals students' understanding or the lack of it. When understanding is probed at a deeper level the learning is often found to be superficial. In order for students to develop deep learning<sup>3</sup> it is critical that they understand what they are learning and how to realise that learning.

---

<sup>3</sup> Deep learning: an intention to understand material for oneself and to critically interact with the content.

Formative assessment practices provide the strategies to facilitate deep learning.

### **What is understood by formative assessment?**

Assessment *for* learning has been the subject of much recent research (Crooks, 1988; Sadler, 1987, 1989, 1998; Black and Wiliam, 1998; Gipps, 1999; Clarke, 2001; Clarke, Timperly and Hattie, 2003) and, as stated by Harlen (2000), involves gathering evidence relevant to students' learning, judging it against expectations, interpreting and using the judgements for specific purposes. Judgements can be made, by comparing against norms, criteria for performance or the student's previous achievement. Evidence about learning, gathered by teachers, can be fed back into teaching and also shared with students so that they have a better idea about how to take their next steps. Such assessment, as declared by Black and Wiliam (1998), becomes formative when students act on the feedback to improve their learning. In order to do this, students need to be provided with opportunities to reflect on their learning; a fundamental principle of constructivism.

In gathering evidence about learning, teachers and students need to be clear about the intended learning outcomes, know how to achieve these, and how they contribute to the longer term goals (Sadler, 1989; Harlen, 2000; Black & Wiliam, 2002; Clarke, 2001; Huinker & Freckmann, 2004). Criteria for evaluating any learning achievements and how to achieve them must be made transparent. Sadler (1987), Gipps (1999), Harlen (2000) and Black and Wiliam (2002) further this notion by suggesting that concrete examples should be provided as models. The exemplars and associated matrix, as described in Chapter One, are developed around this notion. Examples of student work are used to identify learning, and teaching ideas are provided. The learning and assessment activities need to be those that support the learning intentions and raise the expectations of students by asking questions that require higher order thinking (Harlen, 2000).

Skills and knowledge are now known to be dependent on the context in which they are learnt and practiced (Resnick, 1987, cited in Askew, 2000; Gipps, 1999). Therefore facts cannot be learned in isolation and then used in any context. Generalised skills do not develop from context specific learning. As Gipps (1999) states, isolated facts if learnt, quickly disappear from memory because they have no meaning and do not fit into the learner's conceptual map. This then provides a major challenge to teachers as they consider worthwhile goals in which to develop a progression of learning.

The notions of comparability and teachers' ability to assess dependably are issues raised by Sadler (1987) and Gipps (1999). They argue that by providing a definite framework, such as the matrix provided in the national assessment tool, which allows teachers to interpret criteria and standards, it is possible to achieve comparability among schools and to help children acquire evaluative expertise themselves.

Sadler (1987) asserts that a way to specify standards is through a combination of verbal descriptions and exemplars. Exemplars, chosen to be typical of designated levels of performance, are not the standards themselves but rather denote the standards. Descriptions of the standards set out the properties that characterise the designated level of quality. This combination of descriptions and concrete exemplars offers an efficient way of specifying standards. Sadler (1987) argues that such an identification of standards does not mean that the tacit knowledge held by appraisers is redundant, as 'external formulations' cannot cover every conceivable case. Such a framework would also provide a means for achieving a common understanding, among teachers and learners, of what represents progress and therefore provide a way of achieving reliability in the monitoring of progress across schools. A critical aspect to achieving reliability<sup>4</sup> would be the moderation of student work against the standards, and for teachers and students to engage in dialogue about what constitutes the standard. Teachers would need to be taught the process of interpretation and moderation. Gipps (1999) states that exemplars can also be used to explicate to

---

<sup>4</sup> Reliability is "the extent to which an assessment would produce the same, or similar, results on two or more occasions or if given to two assessors" (Gipps, 1999, p. V11).

teachers the nature of the skills being taught and assessed, and as a result teachers' content knowledge can be developed.

Pelligrino, Chadowsky and Glaser (2001) claim that data do not have meaning of their own and their value as evidence can only arise through an interpretational framework. Therefore a framework against which to judge what is important learning, identify progress, and how to measure it, is a critical tool in formative assessment. The National Exemplars and associated Matrix is such a tool. Deciding the next steps in students' learning requires that teachers have a clear understanding of the nature of progression. The next steps in developing students' process skills and attitudes can be identified by comparing students' behaviours and products with indicators of development; that is progression (Gipps, 1999; Harlen, 2000). Harlen (2000) raises the notion of progression as being a significant factor in quality teaching and learning and identifies key aspects as process skills, knowledge, attitudes and expectation of behaviour. Gipps (1999) asserts that progression is the move from novice to expert and this notion of progression is an underlying belief in the National Exemplars and associated Matrix. The matrix has identified a progression from novice to expert in the key aspects of science learning, and is organised around five levels of the New Zealand curriculum. The challenge for teachers is to be cognisant of these indicators, to have shared understanding of them, and to use them in providing feedback to students on their learning.

Feedback to students on their progress is made more effective if it focuses on the learning intention, is non-judgmental and provides information about the next step and how to take it (Crooks, 1988; Sadler, 1989, 1998; Black & Wiliam, 1998; Gipps, 1999; Hattie, 2002; Harlen, 2000; Clarke, 2001). Feedback also sends messages to students about their effectiveness and worth and plays a critical role in students' self-esteem and motivation (Crooks, 1988; Sadler, 1989, 1998; Black & Wiliam, 1998; Gipps, 1999; Clarke, 2001). Information fed to students can only be considered to be feedback when it can be used to close the 'gap' in student learning (Sadler, 1987) and therefore students need to be provided with the opportunity to respond to the feedback.

Sadler (1989) states that a critical condition for improvement in learning is that students come to share the notion of the standard or desired quality that the teacher holds in their head. This then allows the students to monitor the quality of their work and adjust it as necessary. In order for students to access this standard, teachers must share learning goals with the students, convey an operational meaning of quality and help them to identify the next steps in their learning (Harlen, 2000).

Students learn by taking the role of teachers and examiners of others (Sadler, 1989) and in order to do so need the skills of collaboration. In working collaboratively in small groups, students are able to receive and give elaborated explanations, and tasks are the responsibility of the whole group; as a result the burden of failure on individual students is reduced, the perceived ability 'stratification' is reduced (Crooks, 1988), and self esteem and motivation is enhanced. Students frequently accept criticism more readily from their peers who use the language that they understand. As stated by Crooks (1988) and Black and Wiliam (2002), there is intrinsic value in peer assessment and collaboration, which develops the skills and attitudes for self-assessment and the enhancement of learning.

### **Putting the theory into practice: Science pedagogy**

While constructivist and assessment theory identify key aspects of teaching and learning in science, teachers need strategies to put these theories into action. As Ritchie (1998) asserts, the teacher's role is to advise and provoke discussion and debate rather than assign pre-determined activities that may deal with students' questions. Through questioning, teachers learn more about students' pre-knowledge and the gaps and the misconceptions in that knowledge (Black & Wiliam, 2002; Harlen, 2002). This then provides the basis for the next-step in the student's learning.

Questions can provide impromptu interventions as students engage in tasks and can extend students' thinking through immediate feedback on their task.

Such a process allows teachers to utilize Vygotsky's (1992, cited by Gipps, 1999) concept of the zone of proximal development thereby extending students' existing knowledge through scaffolding the learning so that the students begin to use and incorporate the learning into their thinking. As stated by Black and Wiliam (1999) and supported by Harlen (2000), teachers who question students in their learning shift in their role from presenters of content to leaders on an exploration and development of ideas in which students are involved. However, generic strategies such as asking good questions, peer and self-assessment, and feedback can go only so far. Choosing a good question requires a detailed knowledge of the specific subject. As Black and Wiliam (2000, p. 15) state "teachers need a thorough understanding of the fundamental principles of the subject, an understanding of the kinds of difficulties that pupils might have, the creativity to think up questions and then stimulate productive thinking".

Pedagogical knowledge is equally critical to interpreting students' responses, as the responses will provide clues to the students' learning and the difficulties they may be encountering. Teachers with thorough pedagogical knowledge and an understanding of the common difficulties in learning the concepts are more able to support students' learning. In science many of the 'alternative conceptions' held by students are well documented (Osborne & Freyberg, 1985; Driver, Guesne & Tiberghien, 1992, cited in Shepardson, 1997) and can be anticipated by knowledgeable teachers. Teachers then can provide opportunities for discussion of these ideas and activities that will present new information and challenge students' thinking as they work towards an understanding of a more scientific model.

Bransford, Brown and Cocking (1999, cited by Alton-Lee, 2002) also hold the view that there is a dynamic interaction between teachers' knowledge of the discipline and their knowledge of pedagogy, and that teaching does not consist of only a set of general teaching methods. Hattie (2002, p. 22), in his study of expert and experienced teachers, found that content pedagogical knowledge was a defining feature and allowed experts "to organize and adapt knowledge structures to the diverse interests and abilities of their particular students".

Timperley (2003) furthers this notion of the importance of content knowledge when raising issues about teacher expectations. She asserts that there are three aspects to raising teacher expectations: an awareness of higher student achievement, where teachers are presented with information that is discrepant with their existing view about students' capability; that by challenging the beliefs of the impact of teaching on learning, teachers are critiquing their own practice; and the provision of new pedagogical knowledge and content knowledge.

Lezotte (1990) and Good and Brophy (1997, cited by Timperly, 2003) contend that teacher expectations may influence student achievement. Good and Brophy expand this notion as they propose that teachers' beliefs about their students' potential academic achievement, whether they be whole class or individual, become their goals for the students and shape their daily classroom actions, including what they believe to be appropriate curricula and instructional practice. This is evident in teacher planning where teachers are guided by their beliefs about what students need and how they will respond if treated in particular ways. Decisions are made on the basis of how best to achieve these expected goals. These notions support Delpit's (1995, cited by Timperly, 2003) belief that when expectations are low, decisions are likely to include non-challenging and non-academic curricula and teaching strategies which require less teaching to the students instead of more. Conversely, when expectations are high, teachers are more likely to assume that they can and will provide whatever programmes and resources students need to succeed (Reyes, Scribner & Scribner, 1999, cited by Timperly, 2003) and will effect deep learning for students. Entwistle (1992, cited in Gipps, 1999) asserts that the characteristics of deep learning are: an intention to understand material for oneself, interacting critically with the content, relating ideas to previous knowledge and experience, using organizers to integrate ideas, relating evidence to conclusions, and examining the logic of an argument.

Providing opportunities for students to construct knowledge, sharing learning goals and providing next learning steps, and making these next steps clear to students through the use of a framework and 'concrete models', are expectations of quality teaching and learning in science. However, while the

'utopian' state may be made explicit to teachers, it is the quality of the professional development model and the teacher as a learner that are critical to teacher change.

### **What factors interact with teacher change?**

#### *The professional development model*

Professional development is about the improvement and growth of a person's professional abilities, which in education impacts on what happens in classrooms and schools generally. Each teacher within a school is, in part, accountable for the success of the organisation and for their own performance as professionals (Barth, 1990). Ingvarson, Meiers and Beavis (2005) state that a substantial level of professional community is vital to significant change, and identify critical factors of a professional community as being time, analysis and talk about the specifics of what happens in classrooms and what students are doing or saying. In order for the professional learning community to engage in effective professional development, Ingvarson et al. (2005) assert a number of factors have to be present: the opportunity for teachers to focus on what students are to learn and how to deal with the problems students may have in learning the subject matter, engaging teachers in identifying what they need to learn, and, having teachers plan the learning experiences that would help them meet these needs.

It is also critical that teachers be provided with the opportunities to talk about the specifics of their teaching practice, student learning, sharing ideas and supporting each other as they attempt to implement ideas from professional development (Annan, Lai and Robinson, 2003). However, Huinker and Freckmann (2004) contend that in order to improve student outcomes, teacher conversations need to be focused around the learning goals and the decisions and actions taken throughout the lesson in monitoring and promoting student learning. Teachers need to be able to articulate the content the students will learn and identify the aspects of the task that are going to help students learn the content. This enables teachers to make more effective decisions in the

midst of teaching as they have a clear picture about the content that students are learning. In the monitoring of student learning it is essential to focus on how concepts unfold in reaching the goals of the lesson. Teachers must then be able to identify where students are in their understanding and where they are heading in concept development. This includes being precise about the concepts that students' struggle with and the concepts they understand well. Only then, argue Huinker and Freckmann (2004), can teachers make informed decisions about lesson modifications that provide support and challenge for students.

Kennedy (1998, cited by Ingvarson et al., 2005) states that the professional learning of teachers is more likely to improve the learning outcomes for children if it increases the teachers' understanding of the content they teach, how children learn that content, and how to teach the content in a way that is meaningful for the learner. The strong relationship between content focus and the reported impact on teacher practice has also been identified by Joyce and Showers (1982) and Ingvarson et al. (2005) who assert that effective professional development programmes draw teachers into an analysis of their current practice in relation to professional standards for good practice. They also draw teachers into close comparisons of what their students are learning in relation to what students of that age and circumstances are capable of learning. Teachers need opportunities to examine student work collaboratively and in relation to standards, such as those in the exemplars and matrices, for what the students should know and be able to do leads to greater understanding of student outcomes and a greater discrimination about what counts as meeting those outcomes (Ingvarson et al., 2005). This also leads to the deprivatisation of teacher practice and allows teachers to gain feedback from colleagues (Annan et al., 2003; Ingvarson et al., 2005).

In order for teachers to actively participate in their learning, they must identify what they need to learn and identify how this could be done, thus planning the next cycle of improvement rather than having it planned for them. Teachers need time to trial new methods and receive follow-up feedback from colleagues. Reflection on practice and the development of understanding about change is

unlikely to be optimal without timely and insightful feedback on what one is doing. Joyce and Showers (1984) and Schon (1987) assert that teachers need to be given time to reflect on their current teaching practice and clarify their understandings of the new learning. Skills need to be demonstrated and teachers given the opportunity to practice using the skills in a training situation, with feedback and coaching.

The span of time and number of contact hours has significant effects on professional development. Garet, Porter, Desimone, Birman and Yoon (2001, p. 933, cited by Ingvarson et al., 2005) argue “ professional development is likely to be of higher quality if it is both sustained over time and involves a substantial number of hours”. The duration of the professional development, is significant in that the professional community is strengthened over time, as is the number of times participants meet for reflection, collaborative activities such as planning and developing curriculum materials. The contact time, the hours allocated to the development, is also critical to the effectiveness of the professional development.

Increased teacher efficacy is dependent on how teachers think their practices have improved, that is increased competence and evidence that student outcomes have improved. Guskey (1985, cited by Ingvarson et al., 2005) found that asking teachers to try out new strategies and see the affects on students was a more effective professional development approach than trying to change teacher attitudes first. Effective integration of new skills requires programmes to have a clear theoretical foundation supported by research, a strong knowledge base, modelling in real settings, opportunities to practice the new skills and to receive feedback from a coach or supporting teacher (Joyce & Showers, 1982; Cohen & Hill, 2000, cited by Ingvarson et al.; Kennedy, 1998, cited by Ingvarson et al., 2005; Hawley & Valli, 1999, cited by Ingvarson et al., 2005).

Coburn (2003) asserts that two levels of change occur in professional development, surface and deep change. Surface change includes changes to resources, classroom organisation and programmes through the addition of specific activities, while deep change results in change to teachers beliefs,

norms of social interactions and pedagogical principles enacted in the curriculum. Coburn (2003) views 'teacher's beliefs' as teacher's underlying assumptions about how students learn, the nature of the subject matter, teacher expectations for students, and what constitutes effective instruction. These beliefs inform what happens in classrooms. Norms of social interactions are portrayed as teachers' and students' roles in the classroom, patterns of student and teacher talk and the manner in which teachers and students treat one another. She regards pedagogical principles as being inclusive of the way teachers and students engage with particular materials and activities over time, that is, the enacted curriculum. This then has implications for the nature of pedagogical approaches, representation of subject knowledge and learning opportunities for students. The more institutionalised the deep features are in teacher practice, the more likely changes will be sustained over time (Coburn, 2003).

In summary, effective professional development focuses on what students are to learn and plans learning experiences for achievement. Teachers must have sufficient pedagogical and domain knowledge. A focus on student data confronts teachers with hard evidence that may challenge existing perceptions of success as discrepancies raise sharp questions about what is happening and why. The opportunity and expectation that teachers will work collaboratively and support each other in their learning as they share student achievements and reflect on their own practice is fundamental. That teachers accept responsibility for their learning, and determine what they need to learn and how to achieve it, is critical to the success of the development. In focusing teachers on their own practice and domain knowledge, outcomes for students are improved.

### *Teacher as a learner*

The Teacher as a Learner has considerable impact on professional development and is therefore a key element to consider when planning, implementing and sustaining professional development. Shulman and Shulman (2004) assert that teachers who are learners have the following qualities: they are ready, that is they possess a vision; they are willing and therefore

motivated; they are able, they know what to do and are able to do it; they are reflective, they learn from experience; and they are communal, they are participating members of a learning community.

In order to help teachers grow, regular time, opportunities to talk and encourage each other, and to compare and troubleshoot need to be provided. To this end the establishment of learning communities, which promote professional dialogue so that teachers are able to identify discrepancies between theories and practice, construct and reconstruct interpretive frameworks and attempt to make visible much of what is taken for granted about teaching and learning (Le Cornu, 2003), is essential. The aim is to enable teachers to change practices and social relationships in schools and classrooms to maximise participation and learning outcomes for learners.

Dufour (2004) claims that the function of a learning community is to focus on students' learning and that teachers need to work together to ensure that students learn. A systematic process in which teachers can analyse and improve their classroom practice, and engage in on-going cycles of questions that promote deep learning and student achievement is critical to the success of the learning community. Teachers need to analyse their own current practice in relation to professional standards for good practice and compare their students' learning to what students of similar age and circumstance are capable of. The exemplars and matrices provide the 'vision', the standards of teaching and learning in science, and the criteria against which teachers can evaluate their own and others thoughts and actions. Teachers can also compare their students' learning with other students' work.

Pivotal to change is teachers' willingness to change and their persistence in bringing about that change. Guskey (1985, cited by Ingvarson et al., 2005) and Dufour (2004) state that the teachers' willingness comes from teachers' recognition that their students' learning and achievement will improve as a result of the teachers' change in practice and understanding. In order to support the teacher as a learner, professional development needs to engage teachers in the pursuit of genuine questions and interests and needs to be embedded in the

culture of the teaching and learning process, with attention being given to both the curriculum area knowledge and the supporting pedagogies. Fiszler (2004) claims teachers' perceptions need to be considered in order to more effectively meet teacher development needs. If anxiety and frustration are overwhelming, then teachers will not be able to resolve the conflict and might retreat to the stability of old assumptions and patterns of thinking. However, in a supportive learning environment, such anxieties can be overcome. Peer and co-mentoring relationships in a learning community are characterised by a sense of collaboration. Le Cornu (2003) asserts that members focus not just on their own learning but how can they help their partner's learning. Noddings (1994, cited in LeCornu, 2003) calls for a caring attitude, as the act of affirming and encouraging others as well as encouraging the best in oneself, is crucial for development or change of teacher perceptions.

The teacher as a learner is fundamental to the success of professional development and ultimately the achievement of quality student outcomes. The purpose and the focus of the professional development, such as a specific framework like the matrix, can also influence the effectiveness of teacher learning.

#### *Understanding the National Science Exemplars and Matrix*

The development of the National Exemplars as a key component of the *National Assessment Strategy* (Ministry of Education, 2000) provided an alternative to National Testing of students at primary and intermediate stages of their schooling. The purpose of national testing was to determine the performance of students in specific curriculum areas and years of schooling. Politicians and sections of society also favoured some comparison of New Zealand students and schools. The exemplars and associated matrix was an educational strategy to address key curriculum, pedagogical and assessment issues. As stated by Chamberlain (2000), exemplars would clarify curriculum expectations through the provision of annotated samples of student work and support a growth

model<sup>5</sup> of learning by clearly signalling educationally significant learning progressions. The exemplars would also clarify evaluative criteria and contribute to assessment for improving learning and teaching, reporting and accountability. Teachers and learners would be provided with information that contributes to teaching and learning processes, and signals important things to watch for, observe, collect information about and act on.

Research and thinking in the field of assessment and primary science (Crooks, 1988; Sadler, 1987, 1989, 1998; Gipps, 1999; Harlen, 2000; Black & Wiliam, 2002; Clarke, 2001; Clarke et al., 2003) challenged notions about the purpose of assessment. Assessment *for* learning, that is formative assessment, became more preferable to assessment *of* learning, or summative assessment. Consequently interest in national testing waned in favour of exemplar development. Exemplars and the associated matrix would provide schools with a tool to moderate their own performance against a national standard and provide teachers and students with criteria and indicators of progression<sup>6</sup> to support their learning within specific curriculum areas.

As stated by Chamberlain (2000) the exemplars would provide national reference points in order to make statements about a student's achievement; they would inform goal setting at individual student, classroom and school-wide levels; students, teachers and parents would clearly recognise improvement; and partnerships focused on learning could be built. The exemplars would provide opportunities for professional reflection and enhance the quality of professional judgements about learning. They would be able to be used to inform evaluations that are ongoing, formative, pluralistic, and qualitative in context, concerned with the whole person in their context and shared with the learner (Gipps, 1999).

---

<sup>5</sup> Growth models acknowledge that learning proceeds at an individual rate; production models advance students according to a specified schedule of pre-determined steps.

<sup>6</sup> Progression is the significant changes in knowledge, skills, processes and concepts across time.

### **Contradictions, gaps and contributions in current research**

While much is written about the need for providing students with concrete examples of 'good quality' work that also identifies the features of worth (Sadler, 1989; Gipps, 1999; Davies, 2000; Harlen, 2000; Black & William, 2002; Clarke et al., 2003) no research could be found to substantiate these beliefs. Many educational communities have developed standards and exemplars, such as the *Exemplification of Standards, Science Key Stages 1 and 2, levels 1 to 5* (SCAA, 1995) and the *Performance Standards: Volume 1 Elementary School* (New Standards, 1997), which provide some concrete examples, but research to demonstrate their effectiveness as a tool is non-existent.

The underlying concept of a matrix of progression is evident in 'progress maps' (Masters & Forster, 1996), 'progressions in investigating' (Hackling & Fairbrother, 1996), First Steps 'key indicators' (Department of Education Western Australia, 1997), 'rubric for understanding' (Wiggins & McTighe, 1998) and the 'indicators of development' (Harlen, 2000). Again, there is no research evidence of the impact of these notions to indicate the success or otherwise of their use in enhancing teaching and learning and, more especially, student achievement.

Recent research on the trialling of the national exemplars and associated matrix (Poskitt, 2002) found that there was considerable variation in the way teachers perceived the exemplars and the associated matrix and their purpose. Teachers' understanding of assessment and their domain knowledge was often a limiting factor in the use of the exemplars. A significant finding of Poskitt's (2002) research was the need for professional development to support the implementation of the exemplars and matrix.

Extensive literature exists that defines and discusses exemplary teaching and learning in science and explores associated issues such as the influence of content knowledge on teacher pedagogy. Effective assessment practice, which promotes the use of 'concrete models' and frameworks (Sadler, 1987) as assessment tools, is also identified in considerable literature. However a

significant gap exists in the literature about the effectiveness of these strategies on teaching and learning.

Through the extensive observation of seven teachers at two schools this study aims to contribute towards and build on current literature about the effectiveness of such assessment tools and practice, and provide further insight into the issues of implementation of the National Exemplars and associated Matrix.

### **Chapter summary**

A review of the literature has suggested that the use of an assessment tool, such as the exemplars and matrix, that provides a framework signalling educationally significant learning progressions and standards and, a model of what the standards 'look like' is fundamental to improving teaching and learning. Standards, expectations and the next learning pathway are defined and can therefore provide the basis of formative assessment, with specific and useful feedback about learning being given to students.

Teachers' content and pedagogical knowledge is critical to student achievement. Without knowledge, teachers are unable to challenge and provoke thinking and therefore restrict students to impoverished learning opportunities. Science teaching and learning, as exemplified in the matrix with its underpinning of constructivism, is intent on causing understanding and thinking to occur as students interact with ideas and their environment.

Effective teacher development is focused on what and how students are to learn, and the needs of teachers in providing the best learning opportunities for their students. Time for teachers to reflect on student achievement, against standards and their own practice, with a view to improving practice, is vital. Teachers' willingness and persistence to change and the ability to work collaboratively as part of a learning community, the 'teacher as a learner', is critical to effective professional development. These principles were

foundational to this research investigation, the methodology of which is the content of the next chapter.

## **CHAPTER 3: Methodology**

### **Introduction**

The purpose of this chapter is to describe the methodology used in this participatory action research study. It also discusses the way in which the study was structured, the data gathering and analysis tools used, ethical considerations, and issues and difficulties encountered during the participatory action research (PAR) study. The chapter is arranged and sequenced under the following sub-headings: theoretical underpinnings, structure of the study, the PAR research cycle, data gathering tools, ethical considerations, issues and difficulties.

### **Theoretical Underpinnings**

#### *Action Research*

Action research has been influential in the world of education and, as Scott and Usher (2000) state, has focused on improving practice. As such, action research has challenged a number of traditions including the distinction between theory and practice and the academic model of research where researchers were viewed as methodological and substantive experts. Norftke and Zeichner (1987) and Somekh (1995, both cited in Cohen, Manion and Morrison, 2000) and Coleman and Lumby (1999) however, view action research as the bridge between theory and practice. Theory and practice continually transform each other, providing new insights and alternative ways of viewing former tacit knowledge and assumptions, thereby broadening teachers' views on teaching, schooling and society. Concerns about relevance, accessibility and the relationship of theory to the practice of research are addressed in action research.

The origins of action research were in curriculum reform that sought to make academic research relevant to the practitioners' problems. Lewin (1946, cited in Cohen et al., 2000) asserted there is a general idea that a change or improvement is desirable, and that change to teacher's practice is a means of

advancing educational practice in general. Ebbutt (1985, cited in Gipps, 1999), like Lewin (1946, cited in Cohen et al., 2000) recognised that teachers could themselves be researchers, with research geared to their practice. Stenhouse (1975, cited by Costello, 2003) and Whitehead (1985, cited in Cohen et al., 2000) also support the teacher-as-researcher notion, especially within curriculum, and see it as a particularly powerful field of curriculum research. Teachers are able to make individual changes to their practice and develop both their pedagogical knowledge and their knowledge of particular curriculum such as science.

Action research is methodologically eclectic (McKernan, 1991, cited by Gipps, 1999) and requires that people remain open-minded about what counts as data or evidence and that researchers analyse their own judgements. As stated by Glesne (1999), it is vital to keep questioning one's own assumptions and perceptions and keep asking the question "why is it this way and not a different way?" Empirical data collected from teachers inform these judgements. Kemmis and McTaggart (1992) argue that all social action is to some degree unpredictable and risky. As a result the general action research plan must be flexible enough to adapt to unforeseen effects and previously unrecognized constraints.

Increasingly, teacher research and 'issues' approaches to practitioner inquiry, especially action research, are positioned as vehicles for radical critique and challenge, designed explicitly to interrogate and alter the arrangements of schooling that perpetuate systematic inequities (Cochran-Smith & Lytle, 1999, cited in Coleman & Lumby, 1999). Thus action research becomes more important as a vehicle for change rather than simply a means of investigation. Nevertheless a tension exists between those who see practical and tacit knowledge as being valid and those who hold it to be invalid.

There are some concerns as to the efficacy of teachers as researchers. Scott and Usher (1999) argue there is an assumption in action research that human beings are knowledgeable about their own situation and the fact that they are not removed from their own situation, as would a 'scientific' researcher, does

not disqualify their knowledge. Cochran-Smith and Lytle (1998, cited in Coleman & Lumby, 1999) claim practical knowledge generated by teacher researchers, particularly in the classroom, is regarded as low-status knowledge, as 'everyday', excessively local and particular, and possibly trivial. On the other hand as Kemmis and McTaggart (1992) argue, to do action research is to plan, act, observe and reflect more systematically and rigorously than one usually does in everyday life. Action research has increasingly become an accepted method of research and as researchers ensure that the community of researchers scrutinise their methods, it will be viewed as being more rigorous and valid.

In the improvement of practice there are two aspects of action research to promote reflection among the practitioners and to bring about change. Schon (1984, p. 41) discusses the importance of "reflection, in a context of action, on phenomena which are perceived as incongruent with intuitive understandings or a reflective conversation with the situation". As a result the reflective practitioner will elucidate their understanding of the processes in education and enhance their own learning. The promotion of change and Schon's concept of reflection-in-action are linked, with the emphasis being on the action. Practical action research, which encourages 'reflection-on-action', is designed to promote teachers' professionalism by drawing on their informed judgement (Grundy, 1987, cited in Cohen et al., 2000) and attempts to understand and interpret the social situation with an intention of improvement. Kemmis and McTaggart (1992) further this notion and posit that the approach is only action research when it is collaborative, though it is important to realise that the action research of the group is achieved through critically examined actions of the individual group members. Elliott (1991, cited by Cohen et al., 2000) supports this view and states that action research is an empowering activity and has to be at a collective rather than individual level, as individuals do not work in isolation from each other, but are shaped by organisational and structural forces.

Altrichter (1993) raises a contrasting issue with action research: it is in danger of elitism because of the nature of the people who volunteer for the collaborative activity. The strong methodological claims and the reintegration of

practice into the research process are demanding and often incompatible with the existing conditions and culture in which professionals work. Action research is clearly situated in a political context and is based on a concept of a socially responsible professionalism. Still the question needs to be asked about who decides what is acceptable and desirable, and who benefits or is empowered by the action research. Action research is unquestionably a political process because it involves making changes that will affect others at an individual or group level.

### *Participatory Action Research*

Cohen et al. (2000) argue that action research is not done *on* other people, but *by* particular people on their *own work* to help them *improve* what they do, including how they work with and for others. This understanding is the essence of participatory action research (PAR). Action research focuses on practical issues that have been identified by participants and which are problematic yet capable of being changed (Elliott, 1978, cited in Cohen et al., 2000). In this way it is participatory as people work together towards the improvement of their practice. It is important then that it takes place in its natural setting for sustained change to occur.

Greenwood, Whyte and Harkavy (1993) posit there are two important dimensions of PAR: the participatory intent of the research process, and the degrees of the participation actually achieved by a particular project. The degree of the participation in the project is influenced by the nature of the problem, the aims and capacities of the participants, environmental conditions that exist and the skill of the researcher. A participatory intent ensures that there will be a participatory process and that the facility exists for this to occur, such as the opportunity for participants to reflect on their own practice and share and collaborate on results with the rest of the research team. Participation at first generated by the researcher, becomes part of the participatory processes as participants identify and examine elements of their own practice that are of most concern to them. As Greenwood et al. (1993, p.1 76) state, participation "increases over the life of the project as a dynamic response to emergent

possibilities". Thus PAR is an emergent process, dependent on the participants and the conditions.

Kemmis and Wilkinson (1998) assert PAR offers an opportunity to create forums in which people can join one another as co-participants in the struggle to remake the practices in which they interact and involves learning about the real practices of people in particular places. Each individual in a group tries to understand the ways in which their knowledge shapes their sense of identity and to reflect critically on how their present knowledge frames and constrains their actions.

The role of teacher as a researcher is complex. The teacher has a responsibility to extend their own learning through empirical enquiry, meet school requirements and standards, while at the same time risk-taking in changing their practice, contribute to the professional learning of colleagues, and develop worthwhile and meaningful learning opportunities for individual students. The commitment to so many purposes, audiences and responsibilities raises ethical concerns as to where the teachers' primary responsibility and duty should be.

Questioning of teacher expertise in research methodology and data collecting techniques, and the general value of their outputs, has been raised not only by researchers but by teachers themselves. As Dadds (1995, p. 5, cited in Cohen et al., 2000) states, "educational theory is a commodity made by the experts in other higher institutions". However there is a growing body of support for accepting as valid the knowledge that is generated by those actively involved in the research (Hubbard & Power, 1999). The support is based on several assumptions: practicing teachers are most familiar with the classroom setting and students; and the potential for a variety of data gathering is great, given the time spent in school is extensive (Keating, Diaz- Greenberg, Baldwin & Thousand, 1998).

PAR strongly encourages continuous learning on the part of professional researchers. This can be realized when professional researchers consider their own practices, the ways in which they collaboratively change the practices of

the participants, and the way they participate and interact with others in these practices. Thus in elucidating their understanding of educational processes, researchers also enhance their own learning and the resultant changes to their own practices and understandings can improve the quality of the research.

*Participatory action research and professional development*

Fals Borda (1979, cited by Kemmis & Wilkinson, 1998) states that participatory action research attempts to help people investigate and change their social and educational realities by changing some of their practices, which constitute their reality, and as such can be an effective means of professional development. Participatory action research has similarities with professional development, such as the systematic gathering and analysis of data (Guskey, 2000), meeting the teachers' goals, focusing on their real and daily concerns, and building on earlier learning and experiences (Birman et al., 2000, cited in Ingvarson et. al, 2005).

The action research model, with its systematic cycle of plan, act, observe, reflect and analyse is in keeping with the way advisers work and therefore is more easily accommodated by the schools and individual teachers. Coleman and Lumby (1999) assert that since action research focuses on the problems of both practical and theoretical importance, it requires those who experience or own the real world problem to be actively involved with the researcher, at least in selecting the problem and sanctioning the search for solutions. In the educational setting, classroom teachers need to see the problem and its solution as being advantageous to them and to the enhanced achievement of their students before fully participating in any action research or professional development project (Guskey, 2000). Democracy in knowledge production gives the participants a stake in the quality of the results, increases the reliability of the information and the likelihood that results will be put into practice (Greenwood et al., 1993). Action research includes intervention strategies and guidance with the ultimate aim of improvement in learning and teaching, and requires the researcher to have an understanding of change processes and

what change is worthwhile and is therefore aligned to professional development.

### **Research study**

Action research was the chosen methodology for this research because, as stated by Ebbutt (1985, p.156, cited in Cohen et al., 2000) "action research is the systematic study of the attempts to change and improve educational practice by groups of participants by means of their own practical actions, and by means of their own reflections upon the effects of their own actions". Elliott (1991, cited in Cohen et al., 2000) furthers this notion and claims the fundamental aim of action research is to improve practice, rather than to produce knowledge. In this research study the teacher participants were involved in the action research process, actively engaged in looking at their own practice, determining where they wanted to be and increasingly, as the action research developed, identifying interventions that would allow them to meet new goals and understandings. As such this research study is more accurately defined as PAR.

Tyler (1949, cited in Cohen et al., 2000) asserted that in order for continuous improvement to be made, it is necessary to have a conception of the intended goals. There can be no change in practice unless there is an awareness and discussion by those in the research study, of what constitutes worthwhile goals. In this PAR study the matrix and the exemplars provided the framework of 'worthwhile goals'. The research study was carried out as part of an in-school professional development in science education and as such the expectation was that improvement to teacher practice and student achievement would result. This requirement sits well with the underlying philosophy of action research and in particular PAR. In this way, the process and the product of action research are intertwined, similarly the methodology and content of this research study intertwine.

## Structure of the Study

### *Research Population*

Two schools were involved in the action research project. School A, an urban decile four full primary school (years 1-8) with a roll of 300 students had requested on-going support in assessment. They had been involved in the Atol Project<sup>7</sup> in 2002 and 2003 and had requested further support with assessment, namely the National Exemplars and Matrix. Because of the teachers' needs and interests and the researcher's 'expertise' in science education, it was decided that the on-going development would be in science and the science exemplars and matrix.

One syndicate agreed to be part of the research project. This involved four teachers. Two of the teachers, teacher 6 and teacher 7, job-shared. They both had responsibility for the class and shared the science topics. The other two teachers, teacher 4 and teacher 5, had their own classes. Three of the teachers had over twenty five years experience and one of them over fifteen years. The children were year three and four and aged between seven and nine. All teachers had previous experience at teaching this age and year level.

School B, is an inner city decile seven primary (years 1-6) school, with a roll of 350 children. A sampling of students using NEMP<sup>8</sup> activities ascertained that there was limited understanding of basic science concepts and this, coupled with a lack of teacher confidence in science teaching and learning saw the senior syndicate engage in a science development in 2003. The development was not school wide as the junior syndicate was engaged in the Early Numeracy Development Project<sup>9</sup> and it was considered to be counter productive to be part of two initiatives. In 2004, the junior syndicate engaged in the science development while the senior syndicate participated in the Advanced Numeracy Project<sup>10</sup>.

---

<sup>7</sup> *Assess to learn Project*: a Ministry of Education professional development assessment project and initiative.

<sup>8</sup> National Education Monitoring Project.

<sup>9</sup> *Early Numeracy Development Project*: a national Ministry of Education initiative for junior students and teachers.

<sup>10</sup> *Advanced Numeracy Development Project*: a national Ministry of Education initiative.

The junior syndicate comprised five teachers. All of the teachers were involved in the in-depth science development but only three teachers agreed to be part of the formal research project, which included gathering data during 2004. Of the two teachers who declined to be part of the research study, one was to retire at the end of 2004 and the other had taken on management responsibilities for the first time and was concerned with the workload she might encounter and her ability to do both tasks well. The three participating teachers were experienced teachers. Teacher 1 had fifteen years experience; teacher 2 had nine years experience and teacher 3 had more than 25 years experience. All three teachers had previous junior teaching experience. The age range of the children was five to seven year olds and they were classified as year one to year three students.

The schools were selected from those that wished to participate in school development, thus making it easier to engage teachers over a sustained period of time. By selecting two schools, a more diverse research population was observed. The teachers participating in the research project were competent classroom teachers. Two of the teachers expressed an interest in science, the other five teachers, by their own admission, lacked enthusiasm and interest. The teachers at School A had some solid understanding of assessment and some effective assessment strategies.

Data were collected over the four school terms of 2004. School A participated in three cycles of research. The three participating teachers at School B engaged in three cycles of action research and two of the teachers continued on to complete four cycles. Each cycle of research included a 'taught' science unit and each unit covered a different contextual strand from the National Science Curriculum. The contextual strands: the physical world, the living world, the material world, and planet earth and beyond, are the contexts through which scientific knowledge is identified and developed in the New Zealand Curriculum. Two integrating strands: investigating, and the nature of science and its relationship to technology, are developed within the contextual strands.

### *Action research cycle*

The action research cycle was the same for each of the two schools. Initial meetings to explain the study were held with the teachers and the principal. The roles of the teachers and the researcher were discussed and clarified, with explicit and achievable actions determined. Teachers and principals identified the goals they wished to achieve as a result of being involved in the research study. Time frames and dates for the cycle of planning, teaching, observation, reflection and interviews, and determining the next-step were set. Each syndicate participated in the programme, outlined as follows.

### *Timetable*

An initial meeting was held, with the school principal and teachers, to explain and seek consent for the Action Research Project.

### *Activity schedule*

Over a four-week period, per term, the following activities took place:

- one in-school planning session
- two in-class observations
- one after school intervention meeting
- one after school reflection/feedback, 'setting the next step' session
- one in-school interview session with each teacher participant.

### *Planning for action*

The initial planning session comprised an introduction to the National Science Exemplars and associated Matrix, and the purpose, nature and structure of the exemplars were discussed. The session also included formative assessment theory and practice. The unit to be taught was collaboratively discussed and planned, but with the understanding that teachers needed to adapt the unit to meet the needs of their children. Learning intentions, the success criteria, and the appropriate learning activities were identified. Learning intentions expressed the conceptual science goals, the science processes and aspects from the science matrices. The success criteria contained the indicators of achievement

for the learning intentions. These success criteria were to be observed in the tasks or learning activities developed by the teachers. Some professional development around science conceptual knowledge and pedagogy was necessary so that teachers could 'teach' the science unit.

### *Observations*

In most cycles, two observations were carried out over the period of the unit being taught. An intervention meeting followed each of the observations.

#### Observation One

Initially the researcher observed one lesson in the unit sequence, and recorded as field notes the interactions between the teacher and the students. As the research progressed observations also included child-to-child and, teacher to individuals or group interactions.

### *Interventions*

#### Intervention One

At the end of each observation cycle a meeting was held to share with the participants of each school what had been observed and to ascertain their understanding and perspective of the lesson. It was also necessary to gauge whether the researcher's interpretation was valid. Teachers shared stories of the children's learning and activities that they deemed to have worked well. They elicited ideas from the group, which included the researcher, about how to develop children's thinking and knowledge and how to adapt activities to better meet the children's needs. Teachers also sought clarification of their own science knowledge and understandings.

#### Observation Two

This was the second in-class observation within the 'taught' science unit.

## Intervention Two

The teachers engaged in discussions about their practice and the achievement of the children. They reflected on what they saw as the next step for them personally and for the children. They reviewed the science exemplars and the matrices and discussed issues, difficulties, successes and where to next. The researcher fed-back data gathered, as illustrated in the extracts following, and helped them identify changes in their practice. The researcher also challenged the teachers' thinking about their practice and raised issues, as they went through the reflection cycle, of research-led 'exemplary' science pedagogy and student achievement.

Feedback: To Teacher 2 (FN 3: 37)

*By providing a variety and a number of activities in which the children explore a concept; you have helped them develop a depth of knowledge.*

*Having them work in groups, where they can talk and try out their ideas and become aware that other people have different ideas, has further enhanced this.*

*You have provided the opportunities for children to use aids, the earth and the sun, to help them with their explanations. You have also modelled how this might be done.*

*What do you see as being the next step for you and for the children?*

After some discussion where ideas and issues were shared by the teacher and the researcher, the researcher made the following suggestion to the teacher participant:

Feedback: To Teacher 2 (FN 3:37)

*Your next-step could be allowing the children to have more control over and management of the way they carry out their investigations and discussion.*

*They have lots of modelling and are perhaps ready to apply some of this knowledge and accept responsibility for it. This may mean that activities are not always highly successful or organised. However this is an important part of the learning, as well. Perhaps you could begin by getting them to suggest how things could be done.*

Feedback: To Teacher 2 int C4

(R int C4) *What changes have you made to your practice?*

(T2 int C4) *I have been trying to stand back a little bit and give them a bit more independence. Because I think with my science teaching in the past I have been really really organised. I have been trying to get them to do the investigating a little bit more for themselves.*

Discussions took place after school and were sometimes part of the regular syndicate meeting time, and at other times they were expressly arranged for the specific purpose of discussion and reflection.

### *Interview*

The interviews highlighted and identified critical issues to be developed in the next action research cycle.

The Action Research cycle was repeated over the three terms for School A and four terms for School B, and always with the expectation that the teachers would drive the action research and that the pattern would be modified in order to be responsive to the needs of their students and themselves.

### *Data gathering tools*

The main data gathering tools for the action research study were reflective journals, observations, interviews and document analysis. Each of these methods is considered in the following sections.

#### Reflective journals

Teachers were encouraged to keep a reflective journal of their journey (Kemmis & McTaggart, 1992). The purpose was to record reflections about the practices they were examining as well as their learning about science concepts and pedagogy and the action research process. Over the duration of the 'taught' science unit, teachers were expected to record significant moments, thoughts

and actions. Teachers kept these personal journals in ways appropriate for them. However they were used to guide their own reflection and practice and provide evidence to support their ideas and their learning journey. The recorded data and reflective comments were available for triangulation purposes.

### Observations

As stated by Glesne (1999), participant observations provide the opportunity for the researcher to become a 'trusted friend' and develop sound relationships if carried out in an unobtrusive and non-judgemental way. The researcher learns first hand how the actions of the research participants correspond to their words, observes patterns of behaviour, experiences the unexpected and develops a quality of trust with others that motivates participants to tell the researcher information they might otherwise not. Further to this, interview questions develop through participant observation and are connected to known behaviours and the answers can therefore be better interpreted. Observation also informs the researcher and participants about other areas for investigation and development. A purpose of observation is to provide the basis for immediate reflection, and more so in the near future as the cycle of action research runs its course. Observation can also serve to meet the purposes of triangulation of data sources.

The observations, while planned, were sufficiently unstructured to allow the situation to unfold and issues to emerge. Field notes (see Appendix 2) (Lofland & Lofland, 1984, cited in Scott & Usher, 1999) were kept in order to record: a descriptive running commentary; observation of the action process, which included teacher pupil interactions, lesson format and content; effects of the action (intended or unintended), and the way circumstances and constraints influenced the planned action and its effects. The flexibility and lack of pre-judgements by the researcher, was an advantage, allowing the researcher to pose questions and create new provocations for the participants (Adler & Adler, 1994, cited by Gipps, 1999). Observational methods of data gathering allowed the researcher to further analyse and interpret the data at a later stage in quantitative and qualitative ways.

As posited by Glesne (1999), observation can range from mostly observation to mostly participation, and may change over time. Change was evidenced in this action research study where the first cycle was only observation, with all commentary and interactions between the teacher and students recorded as field notes. As the students and teachers began to see the researcher as a highly interested and 'trusted friend,' she was included as part of the group and as a fellow research participant. Children readily shared their learning with the researcher, thus allowing her to question their thinking, understand their perspective, and based on their needs identify next steps for the learning (science understandings) and the action research development. Thus effective interventions that would elicit change were introduced to the research participants. The researcher was able to support teachers to think critically about the data and then collectively determine appropriate courses of action. Participation by the researcher provided a much deeper understanding and awareness of the site, and the teaching and learning in science. As a participant, the researcher became more aware of particular needs and practices of individual teachers. Teachers also began to ask for support and ideas while the researcher was in their classroom. They were anxious to share what they were doing and the exciting learning happening for the children.

As teachers gradually accepted more ownership of the research they were able to effectively determine their own pathways. Interventions and changes to practice were considered and challenged before being adapted, adopted or discarded. However, as Scott and Usher (1999) state, it is critical to bear in mind that researchers cannot fully participate as they are involved in the act of translation and, at the same time making judgements (utilizing their value system) about the setting, which they are investigating. Glesne (1999) argues that it is vital to keep questioning one's own assumptions and perceptions and to ask, "Why is it this way and not a different way?" The role of the outside researcher, therefore, was one of encouraging critical reflection in and on practice.

An advantage to staying in the situation over a long period of time (the three or four school terms of the action research study) was that the researcher was

able to observe how events evolved over time, and to record the dynamics of situations, the people, personalities, contexts, resources and roles (Cohen et al., 2000). Staying in a situation for a longer length of time also served to make the data gathered more valid and reliable. At the end of each session the field notes were analysed for meaning and the question asked, "What is going on here?"

Analysis of the data also provided ideas for continuing development and data for discussion. In many instances, teachers were unaware of what was happening as children engaged in group work, due to the inability of being able to work with all of the groups at one time, and the data collected through researcher observation provided them with some insights into the learning that was occurring.

On-going reflective thinking, analysis and interpretation by the researcher was likewise documented in a journal, along with emerging issues, ideas and difficulties and details of interventions. Spradley (1979 and Kirk & Miller, 1986, both cited in Cohen et al., 2000) suggest observers should keep four sets of observational data: notes made in situ; expanded notes that are made as soon as possible after initial observation; journal notes to record issues, ideas and difficulties that arise during the field work; and running records of ongoing analysis and interpretation so that observations are systematic and thereby increase the reliability of data. As data themes became saturated the researcher was able to widen the scope of data collection and include observations of interactions: child to child and teacher to individuals or groups of children.

### Interviews

The research interview can provide significant data and is described by Kvale (1996, p. 11, cited by Cohen et al., 2000) as an "interchange of views between two or more people on a topic of mutual interest". Interviews acknowledge the importance of human interaction for knowledge production and, as Kvale (1996, cited by Cohen et al., 2000) asserts, emphasise the social situatedness of research data. The purpose of the interviews is critical to the data gathering

process and enables participants, be they interviewees or interviewers, to discuss their interpretations of the world in which they live, and express how they regard situations from their own perspective.

When used in conjunction with other methods of data collection in the action research, interview validates, clarifies or increases the knowledge gained. Cohen et al. (2000) suggest that a more responsive and informal interview, where what is being sought is more uncertain, allows the researcher to respond to what emerges. In this way the researcher can follow up unexpected results, validate other methods or go deeper into the motivation of respondents and their reasons for responding as they did. However a disadvantage is that the process and data are prone to subjectivity and the bias of the interviewer (Oppenheim, 1992, cited in Cohen et al., 2000).

The PAR study used a combination of structured and unstructured interviews (Morrison, 1993 cited in Cohen et al., 2000). The structured approach provided the participants with a format that specified in advance, in outline form the topics and issues to be covered. A core set of questions (see Appendix 3) were used as prompts, so that the data collected provided insight into the research question:

*What impact do national curriculum exemplars and the associated matrix have on teaching and learning in science?*

The interviewer then decided on the sequence and wording of the questions during the course of the interview. Advantages of this approach were that the outline increased the comprehensiveness of the data and made data collection more systematic for each of the respondents, and allowed the participants to have reflected on the questions and be prepared, thus eliminating some of their anxiety. Logical gaps in data could also be anticipated and closed. The interview, however, could still remain fairly conversational and situational. Disadvantages were that important and salient topics could be inadvertently omitted and that any flexibility in the sequencing and wording of questions could result in different responses thus reducing comparability of responses.

Hour-long individual interviews were conducted with each of the teachers participating in the research study, at the end of each cycle of the participatory action research. With the teacher's permission these interviews were taped and transcribed. A copy was provided to the participants. The interview process and purpose was carefully explained and teachers were given a guarantee of confidentiality, and told that nothing they said would do anything to harm them or their students. They also had the option of declining to participate in the interviews or declining to answer specific questions. None of the participants took those options.

Data were able to be collated from site to site and teacher-to-teacher. In order to form generalizations and aggregate data, some of the interview questions remained the same from school to school and cycle to cycle. As the research progressed it was necessary to adjust the research questions to take into account emerging issues and trends. The participants also raised questions of their own. At this point the interviews became more informal (Morrison, 1993, cited in Cohen et al., 2000).

An advantage of this method is that it increases the relevance and salience of questions and interviews are built on what emerges from observations. A disadvantage is that different information is collected from different people. The approach is therefore less systematic and comprehensive if certain questions do not arise naturally. Data organization and analysis can also be difficult. As the data collected were to be categorized and classified at a later stage it was vital that the respondents' 'meaning' was interpreted and clarified during the interview.

While group or focus interviews would have been cost and time effective for the researcher, none, apart from the two teachers who job-shared and who had their interview together, wanted to do this. They valued the opportunity to engage in reflection and discussion about their practice and learning without being distracted by other teachers' concerns.

### *Document analysis*

Document analysis of teachers' unit planning, the proposed activities to support the learning outcomes, student work, assessment data collected during and after the unit, provided insight into the changes made to teachers' science pedagogy and understanding.

### *Transcript analysis*

While words in a transcript "are not necessarily as solid as they were in the social setting" (Cohen et al., 2000, p. 282), analysis and coding of the transcripts (see Appendix 4) provided key themes and pathways for the action research study. As stated by Cohen et al. (2000), the biggest tension in the data analysis is between maintaining a sense of wholism and atomising the data. In analysing the data the following strategies (Miles & Huberman, 1994, cited in Cohen et al., 2000) were used: noting patterns and themes, which may stem from repeated themes and causes or constructs; seeing plausibility, through using informed intuition to reach conclusions; clustering, or the setting of items into categories; making metaphors, or the connecting of data to theory; identifying and noting relations between variables; building a logical chain of evidence, noting causality and making inferences; and making conceptual and theoretical coherence.

Each transcript was summarised and then analysed by repeated use of words or phrases, for patterns, trends and relationships. Clear trends emerged over the research period. This analysis was then compared teacher-to-teacher and site-to-site where commonalities and differences were identified.

At the end of each observational phase, trends were feedback to the teachers in order to facilitate professional discourse and reflection about their practice. The action plan for the next cycle was planned collaboratively, with increasing teacher ownership and direction as the research proceeded.

*Ethical considerations*

Bresler (1996, cited by Alton-Lee, 2001) argues that ethical practice in classroom research demands of the researcher 'contextuality', or researcher understanding of the complexity and the relevant contexts that shape what happens in classrooms. Advisers, as classroom practitioners who in the course of their everyday work regularly interact in a variety of classrooms, are well placed to undertake participatory action research in the ethical manner described by Bresler (1996).

The two schools selected for this project nominated science as their professional development focus for the year. The action research project strengthened the school development and benefited the researcher. In terms of the development, more time was allocated to in-school support and thus enhanced teacher practice. The concentration of the research, that is the length of time, the observation feedback and observation cycles, was more demanding of teacher time and as such needed to be clearly explained with the provision that teachers could choose to withdraw from some of it, if it became too demanding on their workload. Two teachers from School B chose not to be research participants and withdrew from some of the in-class observations and all of the interviews. A third teacher, from school B, withdrew from the fourth cycle, due to ill health. However the school was committed to the science professional development and expected all teachers participate fully in all activities other than the interviews and some in-class observations.

In order to avoid issues of teacher overload and to ensure that the research project was not jeopardized, it was critical that the teachers and the school management (the Principal and the Board of Trustees) understood the commitment involved and the purpose of the research. To this end an information letter was sent to the Board of Trustees and Principal (see Appendix 5). The research project was able to fund Teacher Release Days<sup>11</sup> for the research participants. Participants were released for one half day for the initial intervention at the beginning of each cycle. Participants were also released for

---

<sup>11</sup> Teacher Release Days: The cost of a relieving teacher is paid to the school so that the participants can be released from classroom duties.

individual interviews. Other meetings took place at the end of the school day. In this way the extra workload was a little more easily assimilated into already busy lives.

### Consent

Issues of informed consent arose only in so far as the data collected were used for research purposes and not just for the purpose of school and teacher improvement. The participants were accorded respect of their privacy and were guaranteed, as much as possible, (Massey University Human Ethics Code), confidentiality in that they would not be identified in any way. The research question, being open and holding no researcher bias, along with the aggregation of data across two schools lessened the concerns of teachers about being identified. Interestingly, both groups of teachers expressed a desire to meet and this was duly arranged. They were most eager to share stories of their learning and that of their students. The purpose and the audience for the research were made clear to the participants. All individual data were shared with the respective teachers.

### Teachers' voice

In order to ensure that both the researcher and the teachers brought their insights to bear upon the data, a process of dialogue was critical. This process was enhanced by the meeting opportunities within the action research cycles as described previously. Cladinin and Connelly (1988, cited by Alton-Lee, 2001) and Brobeck (1990, cited by Alton-Lee, 2001) challenge as unethical, research that makes judgements about practice that discounts or ignores the voice of the teacher in determining the significance and construction of meaning of classroom events. In all interactions with the participants their voice or opinion was sought. Each session began with the expectation that they would share what was happening and why. As the discussions unfolded the participants challenged each other's thinking and practice. Each participant knew that his or her voice was valued and valid and that collectively understanding of good practice would be constructed.

Each participant was viewed as being the expert in his or her own classroom and treated accordingly. As Scott and Usher (1999) posit, the way the researcher behaves towards the participants in their research determines the status of the data and the conclusions formed. This then obligates the researcher to make explicit their behaviours and their role in the construction of knowledge formed from the research. The participants viewed the researcher as having some of the knowledge, and equally challenged her assumptions and views.

#### Conflict of interest

Consideration was given to possibilities of conflict of interest arising, such as being an adviser and distinguishing between that and the role of researcher. Appropriate action was identified. Adviser code of conduct would prevail and the needs and the rights of the school would be paramount. The rights and responsibilities of all parties were negotiated at the outset of the research project. Happily a conflict of interest did not arise.

Being in classrooms requires that respect for the teacher and the children is shown and that every effort is made to protect their self-esteem. As with advisory work, trust is a critical aspect, as is confidentiality. Getting to know the teacher and children prior to the start of the research and being a co-learner and co-participant helped to establish a good working relationship.

#### *Issues and difficulties*

An enduring critical issue with action research is whether it is indeed research. Cohen and Manion (1989, cited in Cohen et al., 2000) argue that action research focuses on a specific problem in a particular setting and is not rigorously scientific. They also claim that because it is situationally specific it cannot be extended beyond that situation and therefore lacks validity and generalisability, thus not meeting underlying beliefs about research. Much criticism levelled at action research is that it does not have a critical dimension. Altrichter (1993) supports this notion and calls for action researchers to scrutinize their 'methods-to-use', as research methods are no longer a given.

He also states that research methods should be put up to the research community to be scrutinized, thus developing a set of practitioner-based rules that would then validate action research as an acceptable research methodology. Winter (1989, cited by Cohen et al., 2000) unlike Cohen and Manion (1989, cited in Cohen et al., 2000) claims action research requires a validity model of its own. In order to minimize issues of validity in action research projects, consideration needs to be given to triangulation and sample size of the research population.

### Triangulation

Triangulation is described by Cohen et al. (2000) as the use of two or more methods of data collection which attempt to map out or explain more fully the complexity and richness of human behaviour by studying it from more than one stand point. Thus this research study used a variety of data gathering methods (as discussed previously). The recognition that the use of one method may bias and distort the researcher's picture of the slice of reality being investigated was also taken into account (Lin, 1976, cited in Cohen et al., 2000). Lin also argues that the more the methods contrast with each other the greater can be the researcher's confidence in the validity of the data. However, Fielding and Fielding (1986, cited in Cohen et al., 2000) hold that methodological triangulation does not necessarily increase validity, reduce bias or bring objectivity to the research as researchers always view data from their own way of 'knowing'.

Cohen et al. (2000) identify a number of methods of triangulation and argue that using a variety of methods does increase validity. Time triangulation involves repeat visits to teachers, in order to see if changes are habitual and are therefore embedded in practice. In this research each of the teachers was visited not less than four times and sometimes six, during each term they participated in the research. The visits included initial planning, observations, interventions and interviews. While three terms for School A and four terms for School B were a significant time frames, the opportunity to continue or follow-up the research over a greater length of time provided further insightful data. Space or cross-sectional triangulation was also a feature of this research as two

individual schools were involved in the research. As observations occurred at both a group and individual level, another means of triangulation was utilised.

Sampling size gave credibility to the research, with seven teachers and two schools. Sufficient data were gathered to be able to make generalizations and inferences from them to other cases and settings, and will be discussed in Chapter 6.

### Validity

Validity is dependent on the fit between what the researcher records as data and what actually occurs in the natural setting being researched (Cohen et al. 2000). Participant checks on the data and researcher interpretation, debriefing by peers or collaborators, prolonged engagement in the field, reflective journals, triangulation and persistent observations in the field confer dependability. By contrast Ruddock (1981, cited in Cohen et al., 2000) claims that qualitative methodologies, whilst possessing immediacy, flexibility, authenticity, richness and candour, are criticized for being impressionistically biased, commonplace, insignificant, ungeneralisable, subjective and shortsighted. However, Cohen et al. (2000) state the strength and reliability of qualitative research is that it is context and situation specific, authentic, comprehensive, detailed, honest, and is meaningful for respondents. It should be remembered that the importance of action research activity is its enhancement of teacher understanding about their practice, action within it, and the situation in which they work.

### Chapter summary

This chapter has described the methodology of Action Research and how it is put into action. Similarities and differences have been drawn with the professional development method that advisors customarily undertake in their advisory role of providing indepth professional development. Issues, concerns and methods related to access and the data collection have been discussed. Aggregation of data and data analysis required for the development of emergent themes was explained. The next chapter discusses the findings of the participatory action research study.

## CHAPTER 4: Findings

### Introduction

The intention of this Participatory Action Research study was to investigate the impact of a National Assessment tool, the Exemplars and associated Matrix, on teaching and learning in science. In developing an understanding of the impact, the researcher was constantly challenged to view the data from three different perspectives: a learning, teaching and research perspective. The 'voices' of the students and the teachers provided rich and detailed data as teachers and students connected with science and came to understand when and how learning occurred and how it was best facilitated.

As the action research iterated through four cycles, themes emerged as being significant and became more densely textured over time. Other themes emerged and dissipated as teachers' and students' practices changed and evolved. Whilst it is impossible to take the reader through all the themes, issues and solutions of the PAR study, the strongly converging themes, in which data were triangulated across methods, as well as within methods, are shared with the reader.

This Chapter then, describes the purpose of the study, the organization of the data over the four cycles (as outlined in the Table following), the themes to emerge and presents the Findings of each of the Cycles.

## Organisation of Data

<b>Table 2: Organisation of Data</b>	
<i>Action Research Cycles</i>	<i>Presentation of Data in each Phase of the Action Research Cycles</i>
Plan	A Planning for Action Determining starting point Planning the science unit to be taught Professional development before action
Observe	B Observations of Teacher Participants
Act	C Interventions (two per cycle)
Reflect	D Reflection: Individual Interviews Collation of data from Individual Interviews: Tables 1-16 Appendix 6 Key trends to emerge from data

In keeping with the action research methodology of 'plan, act, observe and reflect' (Kemmis & McTaggart, 1992), data from each of the four cycles undertaken in this action research study are organised according to the headings, as shown in Table 2 above. Data from each cycle informed the next iteration. The *Planning for action* phase occurred prior to the *Observation* phase. This was necessary as teachers needed to plan the unit of work they were to teach, become familiar with the National Exemplars and Matrix, and in the case of School B, became familiar with formative assessment practice.

Within the *Observation* phase of each cycle, two observations of each teacher occurred over a three or four week period. Each observation was followed by an *Intervention* session. In the intervention session teachers responded to observational data collected by the researcher, and collectively generated solutions to emerging trends. A benefit of having intervention sessions at the end of each 'observation' day was that knowledge and resources about science content or pedagogy could be shared so that teachers were able to continue with the teaching of the unit and not become dispirited when they were working

beyond their comfort zone. The professional development was viewed by the participants, as being timely and effective.

The *Reflection* phase of the cycle contained the individual interview of each teacher, conducted by the researcher. Data collected from the interviews largely informed the next action research cycle. Problems identified during the interviews, by the researcher and the teachers, were fed back to teachers at the *Planning for action* phase of the following cycle and provided the foci for on-going development.

For purposes of efficiency, data are collated according to the cycles undertaken (Cycles 1, 2, 3 and 4) and then further organised according to the phases of Action Research, as described previously. By presenting the data in this way, emerging themes, changes and actions taken are more evident, and are reflective of the action research process in which the teacher participants were engaged.

### **Themes to emerge**

Two sub-themes were revealed against which the investigation into the impact of the National Assessment tools (the Science Exemplars and Matrix) on teaching and learning in science could be interpreted. These sub-themes were the 'teachers as learners', and the nature of the action research and professional development model.

Over the three cycles of action research for School A and four cycles for School B, data from the observations, interviews, informal discussions, document analysis and the professional development sessions 'interacted' with the above sub-themes to reveal two problems:

- Teachers' limited science conceptual knowledge, science pedagogy, and knowledge of the nature of science restrict their understanding and use of the matrices and exemplars.

- Teachers' confused notions of progression in science and formative assessment practices restricted their understanding and use of the exemplars and matrices.

The reader will discern these sub-themes and two underlying problems throughout the four cycles.

The preliminary discussions and professional development in the *planning for action* phase established the participant baseline data, as near as possible, of teaching and learning in science. Teachers' initial views of the National Exemplars and Matrix and science teaching and learning were revealed and impacted on the direction and priorities for development over Cycle One. Each cycle subsequently influenced the direction and priorities of the next cycle, thus putting into effect the phases of Action Research.

## **Cycle One**

### *1A Planning for action*

Discussion about teaching and learning in science and the National Exemplars and the associated Matrix occurred when the researcher first approached the teacher participants at the two schools about becoming part of the Action Research study, and concerns and professional development needs were identified by the teachers and the researcher. Therefore the initial *planning for action* for this action research study had several previously identified foci: developing an understanding of formative assessment (Black & Wiliam, 2002), planning a science unit, identifying science learning goals, developing teachers' understanding of science concepts, and, developing an understanding of the National Science Exemplars and Matrix, their purpose and their features.

The teachers decided to base their three to four week science unit of work around the ideas in an exemplar, which had similar contexts to that which they had selected. Both schools decided to explore structure and function, but in different contexts: School A, butterflies and School B, crabs. The exemplar

provided teachers with learning intentions<sup>12</sup> or goals, and activities on which to base their unit of work. The teachers used the student-teacher conversations contained in the exemplars as a model for questioning: students were asked to explain and justify their ideas so that their thinking could be challenged, thereby developing deeper understanding of science concepts. Following discussions about the matrix and its purpose, the teachers decided to include some aspects from the matrix as learning goals, namely “*Using Scientific Vocabulary*” (Matrix D) and “*Thinking in Scientific Ways*” (Matrix C).

Teachers’ initial reaction to the four matrices was less than enthusiastic as they were overwhelmed by the number of matrices, aspects and indicators (see Appendix 1 for explanation of terms), and were unable to understand them:

(DN 1: 1)      “*heavens, how can we get our head around these? There are far too many and we will never be able to use them.*”

However the teachers decided to start with small beginnings and selected one or two aspects to focus on.

While the teachers from School A had some knowledge of formative assessment, they found it difficult to apply that knowledge to science teaching and learning. School B had little understanding of current assessment practice and therefore professional development on formative assessment (Black & Wiliam, 2002) and assessment practice (Clarke, 2001) was critical, formative assessment being fundamental to good teaching and learning. Identifying the learning intentions and success criteria in a science context revealed teachers’ limited conceptual knowledge and their difficulty in deciding on appropriate learning goals. Teachers were able to identify the activities or experiences they wanted to provide, such as visiting the rock pools, but were unable to decide on the learning that would occur. They were unable to identify ‘structure and function of plants and animals’ and ‘carrying out observations’ as being learning goals. Researcher support was essential in helping teachers to define learning

<sup>12</sup> Learning Intentions (LI) identify learning goals. LI often have associated success criteria (SC), which are the criteria for achieving the LI (Clarke, 2001).

intentions and success criteria, thus establishing worthwhile goals and criteria for determining student achievement in science. The researcher challenged the teachers to identify the learning goals they wanted the students to 'get better at' over time. In responding to the challenge, teachers questioned notions of progression in learning: was the progression related to science conceptual knowledge or was it related to skills such as investigating in science, did progression occur within the duration of a unit of work or did it occur from one unit of learning to the next unit of learning?

Teachers were introduced to a planning method that put into practice formative assessment principles and challenged the teachers to identify key learning goals and criteria for achievement, followed by the development of associated activities. The researcher encouraged teachers to think about the following notions. Do the planned activities develop intended learning goals? Are there sufficient opportunities for students to engage in discourse and to communicate their explanations? In what ways would students have the opportunity to develop a deep understanding of concepts, as opposed to coverage of concepts? Are there opportunities to elicit students' understandings, and for students to have 'real experiences'<sup>13</sup>?

### *1B Observation of teacher participants*

Two observations of each teacher participant occurred over the period of time the science unit was taught. The observations were timed so that the first one occurred at the beginning of the unit and the second one occurred towards the end of the unit. The intention was that data from the observations could be shared with the teachers and any interventions could be responded to within the remaining time frame of the unit of work.

Field notes recorded teachers using aspects and indicators from the matrix as learning goals about which to focus the teaching and learning. Observations of both teachers and students, over the three or four week period (each school

---

<sup>13</sup> Real experiences are defined as hands on learning outside the classroom, access to experts, and experiencing real situations rather than relying on books and the Internet.

had a different time frame) revealed growing confidence and use of the “*Using Scientific Vocabulary*” aspect (Matrix D). Three teachers began to focus on further indicators and aspects from the matrix, such as “*reflect on their learning, change their minds in the light of new evidence or information, explain their thinking*”, and “*investigating*”, to structure the learning activities and the conversations they had with their students. The widening of their focus was the result of growing confidence in science teaching. Teachers began to share the learning goals with their students thereby providing a focus for students’ learning and raising their students’ (and their own) awareness and understanding of the nature of science. One teacher was sufficiently confident to develop the success criteria with students while other teachers provided them for their students. The following extracts exemplify the differences:

- (T1. FN2: 34) Teacher: *How will we know if we have learned everything about crabs? We will know about crabs when:*  
*we can name its parts*  
*say where it lives*  
*say how a crab moves*  
*say what the parts of a crab are for*  
*say what a crab eats.*
- (T4. FN1: 2) *Let’s read out what we are learning today: We are learning that scientists put animals in groups because they have special characteristics. What are the characteristics?*

After critically reflecting on their practice, teachers provided opportunities for students to engage in more meaningful learning. Opportunities were provided for students to engage in discourse where they began to challenge each other’s ideas. As teachers became aware of the ideas their students had they were able to create ‘gaps’ in students’ understanding and establish learning pathways:

(T4. FN1: 28) Teacher: Two things to think about for tomorrow: how can a dead fish lay an egg? Where do the eggs come from?

Student: *That's confusing.*

Teacher: *They sure are. We need to find out a bit more about them.*

This teacher included herself as a learner and modeled her thinking for the students.

(T7. FN1: 8) Teacher: *How might you group the animals?*

Student A: *You could group them mammals and non-mammals.*

Student B: *You could put birds together and put them into ages, such as adults.*

Teacher: *How do you decide if they are adult?*

Student C: *They are different sizes.*

Student D: *But they could be different sized pictures.*

Student C: *They might not have all of their feathers on, they might just be born.*

Student B: *We could have male and female.*

Student C: *How could we tell if it was male or female?*

Teachers changed their expectations of their students' learning outcomes as their own knowledge of the nature of science, and science concepts developed. They supported students to work in scientific ways: students were expected to have theories, to find out whether these were correct, and to provide evidence to support their ideas. Students were encouraged to "accept uncertainty", to "reflect on their learning" and "use scientific vocabulary", these being aspects teachers had identified in the matrices as being important. These changes occurred within Cycle One and were the result of timely reflection on practice, intervention following each observation, and teachers working collaboratively to support each other with science conceptual development. The following excerpt illustrates the changes to teachers' practice and expectations of students:

(T3.FN2: 2) Students' (5 year olds) ideas were recorded under the following categories as they revisited the 'theories' (generated before their visit to the rock pools) about what they would find at the rock pools. Students had to decide:

YES / NO / NOT SURE

Teacher: *Do we need to change our mind about the brown penguins?*

Student: *We need to put the crab under YES*

Teacher: *Did we find a crayfish?*

Student: *No. They are in deep water.*

Teacher: *What about the brown penguin? Would it fit in the rock pool?*

Student: *No it is too big.*

Teacher: *Do you think there are some things you want to change?*

The teacher put the brown penguin in the NO column and continued through the list.

Observations revealed that teachers' ability to ask good questions impacted on the quality of the data they collected and its usefulness in determining the next learning step for students. Teachers' science conceptual knowledge directly impacted on the questions they asked their students. Some questions merely elicited the knowledge students had gained while some teachers were able to probe and extend students' thinking. One teacher (T3.FN2: 4) engaged the students (five years old) in thinking about the crab and raised their awareness of structure, function and habitat. The teacher has also been able to determine the depth of the students' understanding. Another teacher (T7.FN1: 6) generated a list of 'facts' and had no notion of the students' understanding of these facts. Neither did the process of generating a list provide the teacher with ideas about the next learning steps. The following extracts demonstrate the differences in teachers' questioning.

- (T7. FN1: 6) Teacher: *This week we have been learning what?*  
 Student: *Animals and what one is and what isn't*  
 Teacher: *That's great. So what can you tell me about animals?*  
 Student A: *An animal has four legs or two*  
 Student B: *Alive*  
 Student C: *Sound*  
 Student D: *Moving*  
 Student E: *Breathing*  
 Teacher: *They can eat, but they have other things as well - they have babies.*
- (T3. FN2: 4) Teacher: *How is this crab different to that other one? It (this crab) carries its house everywhere and if danger comes it hides. How does it hide?*  
 Student: *It slithers inside.*  
 Student B: *It goes backwards into its house*  
 Teacher: *What would happen if he took all of his legs out?*  
 Student C: *It leaved its house behind.*  
 Teacher: *What happens if he gets too big?*  
 Student D: *He looks for another one he can fit into.*

### 1C Intervention

The intervention sessions occurred after school, at the end of each observation phase. The purpose was to provide an opportunity for teachers to: share highlights, reflect on their practice, for the researcher to feedback observational data, for further problems to be identified, and for professional development to occur. During these informal sessions, discussions were guided by questions, with the express intention of improving teachers' practice through reflection on their own actions. Teachers were also expected to support their ideas with evidence.

The following reflective questions were asked:

- how do you feel the unit is going?
- what are the highlights so far?
- what are the outcomes for students?

- why did you do...?
- why did you do it that way?
- how has your practice changed?
- how can I help you?
- what support do you need?
- what is your next learning step?
- what might you do differently and why?

A significant shift in teacher professional 'talk' became evident in the intervention and reflective sessions in the first Action Research Cycle. Talk changed from a focus on student behaviour to one of student learning and especially the quality of the learning. One teacher commented:

(T2. DNI: 47) *Once I would have done some art, written a story and called it science. The students' knowledge is so detailed. They have gone off to find out very specific information and they are using the scientific vocabulary.*

Teachers began to select aspects identified in the matrix and exemplars as being worthwhile goals to assess, such as "*suggesting explanations*" and "*reflecting on their understanding*", rather than the science knowledge that had been the key focus of assessment previous to this study. Teachers used aspects and indicators, such as "*Using Scientific Vocabulary*", as criteria for reflecting on students' achievement of science concepts. As a consequence their expectations of student achievement were raised as their own and their students' science knowledge developed:

(DN1: 48-49) *The children's knowledge is much greater than we have expected and achieved in the past.*

All teachers were intent on providing the best opportunities for their students to develop their understandings. Teachers reflected on their practice, by considering why they did things as they did, and what they might do differently,

and made changes to their science unit plans so that the needs of the students were met. Discussion revealed teachers were becoming increasingly focused on what the students were learning and how they were thinking, in contrast to a previous focus on activities. To enhance scientific learning, the timing of science learning was changed from the afternoon to the morning. A strong sub-theme to emerge was the 'teacher as a learner', with teachers willingly reflecting on and selecting ways of improving their practice:

(FN1: 17&18) *The classification activities worked really well. Children had to justify what they thought and they were able to reassess what they learnt – what we think we know, what we now know and what we learnt. They had to reflect on their learning.*

While changes to teachers' awareness of students' learning and outcomes developed through the use of the exemplars and the matrices, limited teacher science knowledge constrained their development and created issues that might not have otherwise occurred. The researcher raised the notion of student discourse and the critical part it plays in developing students' understanding, thus challenging some of the teachers, as they felt inhibited by their own lack of science knowledge and were reluctant to allow free discussion, as they did not always have the 'answers'. Teachers also recognised the need for quality questioning, but felt inadequate in their questioning skills to elicit and challenge student understanding if meaning was to be co-constructed. In order to facilitate the changes for students, teachers expressed the need for more teaching strategies to support the learning.

Much of the second intervention in Cycle One was based around developing a common understanding of the matrices as teachers' knowledge of the nature of science and investigating was insufficient to allow them to assign meaning to the aspects and indicators. The notion of progression in science, identified in the matrix, emerged as a challenging issue for teachers, as they were unclear of goals and skills worthy of progressing. The purpose of assessment was revisited as teachers had become confused and held a number of views such as:

(SM. FN1: 30) *Is the purpose of assessment to find out everything the students know or to trick them so that you can find how well they know it?*

Discussion around teaching strategies identified ways of eliciting students' ideas and developing students' conceptual understandings. As emphasis was placed on students exploring and discussing, teachers required on-going support in identifying appropriate learning activities, ways of modifying them to meet student needs and in understanding the science concepts being taught. Teachers referred to the exemplars for teaching strategies and activities at the outset of Cycle One but the exemplars became less helpful as teachers began to meet the identified learning needs of their students.

#### *1D Reflection: Interviews*

Each teacher participated in a reflective session where they were interviewed by the researcher. Teachers were asked to reflect on their practice, student achievement, the matrix and exemplars and the professional development model. Teachers brought student work to share as evidence of student achievement and around which to base reflective conversations. (Refer to Chapter 3).

Data gathered at the end of each cycle were collated according to broad categories: *teacher interaction with the exemplars, teacher assessment practice, teacher pedagogy, and the professional development / research model* (refer to Tables 1-16 in Appendix 6 for detail). Each category was analysed for key trends and is further expanded in the emerging themes: Engagement with the exemplars and matrix, pedagogy, teacher as a learner and the action research model.

#### Engagement with the exemplars and matrix

Engagement with the exemplars and matrix emerged as a significant trend as these tools provided the teachers with teaching strategies, standards, expectations of student achievement and learning goals. Understanding the

matrix emerged as an issue due to teachers' limited science knowledge. Teachers were confused about the meaning and the complexity of the ideas in the matrix but saw it as identifying key goals and understandings in science. Teachers recognized the need for professional development and the need to develop their practice and understanding:

(T4 int C1) *Some of the aspects and indicators are not clear. There are similar ones in different matrices. We need professional development to help us understand them. What is the difference between them?*

The exemplars explicated the standards and set expectations of student achievement beyond the teachers' expectations and caused them to reflect on their own practice.

#### Pedagogy

Teachers' pedagogy developed, especially related to formative assessment practice. Learning goals were shared with the students, and teachers were able to identify student learning and provide feedback to students on their achievement of the learning goals. Teachers identified outcomes other than knowledge and began to identify the differences between students in terms of science understanding:

(T4 int C1) *There is a huge distinction between children's abilities. The matrix has made me more aware and more focused (on the learning). I wasn't convinced that there was going to be big factors between the two levels (of the matrix indicators) and yet it was quite obvious once I got started....I have broadened my own knowledge about teaching science.*

The need to improve teachers' questioning skills was identified by both the researcher and the teachers as being vital, if they were to challenge students and to have them thinking more deeply about their learning:

(T7 int C1) *I will ask a question and then I will say such and such and add in my bit ...I have to keep telling myself, just to let the kids answer then I can ask another question and take them further.*

### Teacher as a learner

The manner in which teachers responded to challenges to their thinking, understanding and practice emerged as being a significant theme. As teachers saw the improved outcomes for students they became more critical of their own practice and its effect on student achievement. The following extract is representative of the comments made by all of the teacher participants:

(T1int C1) *I need to know more. I want to know more. It's the difference between just doing it (providing science activities) and wanting to understand more of what I can do as a content-based learning area, but it (science) is moving into the skills more and more... It doesn't just reflect on the science teaching, but it is reflecting on all of my teaching.*

Teachers' enthusiasm and motivation was evident as they described student outcomes of the 'taught' unit. Focused planning, with clearly identified learning goals, developed from the matrix, and supporting activities contributed to the 'success' of the unit.

At the beginning of Cycle One, the ways in which the teachers worked together in their own school was a point of difference. School A collaboratively planned and supported each other with ideas, getting equipment and resources to share, and were 'in and out' of each others' rooms sharing ideas and information about children. School B teachers met to share administrative details with some planning being discussed and shared, but teachers largely did their own planning or worked with one other member of the syndicate. School B began to work as a team and it was the effect of this, that provided much of the emotional 'high' around the development, as illustrated by the following comment:

(T1 int C1) *The professional dialogue is happening and it is happening because people want it to happen, not because someone has tried to generate it. It is just buzzing.*

Teachers' individual responsibility for teaching and learning in science emerged as an issue. In this action research study all teachers were expected to participate and to then reflect on their own practice and learning. In School A, although they worked collaboratively, one teacher accepted the responsibility for the unit and decided on the context and what would be assessed, this was accepted by the rest of the team. Changes were made to this practice in Cycle One as teachers individually accepted responsibility for the teaching and learning in science.

(T4 int C1) *We are all buzzing; the level of teaching and learning has really lifted. I think it has been your input and the fact that we are more accountable for ourselves.*

#### Action research model

The teachers also valued an outside facilitator supporting their learning, the opportunity to reflect on their practice and having time allocated within their day for professional development, in the '*planning for action*' phase.

#### *Summary of Cycle One*

Teachers' limited science knowledge and pedagogy, their limited assessment knowledge and practice emerged as a problem. However teacher expectations of student achievement were raised through using the exemplars, and the matrices provided the framework of 'how and what' to teach in science. Focused planning and the teachers' determination to improve their practice and science pedagogy were emerging trends in the focus on improving teaching and learning in science.

## **Cycle Two**

### *2A Planning for action*

As Participatory Action Research is an emergent process, the researcher was intent on creating opportunities and the expectation that participants would be involved in the process and determine their own learning. Therefore Cycle Two began with teachers collectively reflecting on the previous unit, and the researcher feeding back trends, to the participants, that had surfaced during the interviews around the emerged themes of: teacher pedagogy, teachers' limited science knowledge and understanding of the nature of science, and the ways teachers engaged with the matrix and exemplars. Trends to emerge were: the use of the matrix to identify students' learning during the unit, and confusion over whether the aspects and indicators were inherent in the learning activities, or needed to be planned for.

The teachers raised a number of issues around formative assessment: what counts for progression in science, what data are useful to collect, how could next-step learning be provided for students, how to provide feedback to students, how to record data in a useful way, and how to identify the differences between levels in the matrix. While teachers could talk about and use assessment data formatively, they still continued to see 'valid' assessment as a summative activity. Both the teachers and the researcher identified a need for more teaching strategies around questioning, eliciting students' ideas, helping students generate questions, developing students' thinking, and investigating.

Increasingly teachers were challenged by the researcher to focus on student learning, as opposed to student participation, and consider how they would structure and manage activities, how they would meet identified goals, and how they could do things differently so that student learning could occur. However, the teachers' limited understanding of the science concepts and the nature of science inhibited their choice of activities and teaching strategies.

## 2B Observation of teacher participants

Classroom observations revealed changes to teachers' practice and their determination to address issues they had identified as being critical to teaching and learning in science, many of which had been made apparent through using the exemplars and matrix. Eliciting students' prior knowledge had become accepted practice and teachers concentrated on co-constructing ideas, challenging students' thinking and having students explain their ideas so that 'gaps' in their knowledge could be identified or created, thereby providing a focus for learning. The following excerpt illustrates teachers' growing confidence and science understanding, and the changed way they interacted with the students and the science concepts:

(T3. FN3: 7) Students were learning how to use a thermometer. Teacher and students looked at the numbers and talked about their use:  
 Student A: *It measures hotness.*  
 Teacher: *Put your hand on the red bulb bit to see what happens. Now take your hand off and see what happens.*  
*Does it go down faster than it went up?*  
 Student B: *It goes slower*  
 Teacher: *What is going on with the thermometer? What are we taking away?*  
 Student C: *Hotness.*  
 Teacher: *What is the word that tells us about hotness?*  
 Student D: *Heat*

Due to the teachers' developing knowledge of science and the nature of science they became aware that investigating (*exploring a situation*: Matrix B) was a goal of teaching and learning in science. A new issue to emerge was the need to develop teachers' questioning skills and strategies to support investigating, rather than simply eliciting the students' knowledge. Field notes recorded the changes to learning opportunities, and consequently the learning outcomes, provided by teachers with students now able to "*collect data in systematic ways*" and "*justify their ideas*" (aspects identified in Matrix B and C) as demonstrated by the following extracts:

(T2. FN3: 14) Students were working in groups using thermometers to measure the temperature of various waters.

Student A: *It is at 30. Write it down.*

Student B: *No everyone has to have a turn.*

Students talked about how to hold the thermometer and how to put it in the container.

Student A: *It is going down fast because the water is much colder.*

Student C: *The wind is blowing on it and making it go down.*

Student B: *The heat is going outside.*

Student D: *The light is getting into number two and making it hot.*

Student C: *The wind is getting into number one and making it cold.*

Student B: *No I think the heat is getting out and the wind is getting in.*

(T4. FNI: 37) Teacher: *Who can explain about a circuit?*

Student A: *It runs in a circle and goes through the wire and the Battery.*

Teacher: *What goes around the circuit?*

Student A: *The current goes in a circle in the wire*

Teacher: *It goes through it, and then goes around again where?*

*Explain about circuits and currents in your group*

Students shared their ideas and attempted to make sense of what they knew and what they have found out:

Student B: *A circuit is something like a circle and makes things Go.*

Teacher: *Add something to it J*

Student C: *A battery, wire, and bulb is in a circuit*

Teacher: *What happens if the circuit doesn't go?*

Student D: *If it is broken it won't work.*

Teacher: *Can you demonstrate that for me?*

Teacher T4 encouraged students to help each other, and add to the conversation especially when students had difficulty in articulating their ideas. Students' achievement and engagement in science grew as the teachers provided more opportunities for discourse, sharing and explaining of ideas, and

constructing meaning, with the expectation that students would support each other's thinking and learning. Teacher questioning of students began to shift from clarifying questions to more challenging ones that sought to identify student depth of understanding.

The emerged problem of teachers' limited science knowledge continued to impact on the teachers' expectations of students as evidenced in the following excerpt:

(T6. FN1: 44&45) Teacher: *Today we have been more successful at getting our bulbs to go. Can someone explain what they did?*  
Student A: *I tried all the ideas in my head and one worked.*  
Student B: *We tried five times*  
Student C: *We put the bulb in the holder and then clipped the wires in the bottom through there (the screw) and it would go through there and around and around through there and it will go.*  
The students continued to share ideas and the teacher responded:  
Teacher: *I have heard a lot of words and ideas. Let's write them up and use some scientific words - flow, circuit...*  
The words were written on the board but meaning was not assigned to them.

The development of teachers' pedagogy allowed them to use strategies that caused deeper understanding: students' learning was revisited to ascertain their understanding, students were helped to make links between learning episodes and teachers provided opportunities for students to reflect on their learning:

(T1. FN3: 1) Teacher: *What did we learn yesterday?*

Student A: *When we put our hand on the table yesterday, the hot went into the table.*

Teacher: *What happens when we open the door?*

Student B: *Hot air went out.*

Teacher: *What happened to the air in our classroom?*

Student C: *It got cool.*

## 2C *Intervention*

In the meetings with the researcher, discussions became increasingly teacher led, rather than researcher led, and teachers challenged each other's ideas and practice. As a result of increased teacher understanding of science concepts and pedagogy, students were given more independence, were more aware of working scientifically, were investigating and using equipment, and were providing explanations for their ideas. An emerging trend was the teachers' ability to reflect on and identify areas of change in their own practice and areas requiring further development, as illustrated in the following excerpt:

(T5. DNP: 6) *The matrix made me realise that 'knowledge' isn't everything in science. There are other aspects and teachers can deal with those. You need to keep science simple and develop thinking skills etc.*

In becoming more skilled at reflecting on their practice, teachers were able to identify several issues: their limited conceptual knowledge inhibited their ability to provide a variety of activities in which to develop students understanding, their lack of confidence and knowledge of the investigative process and their need for better questioning skills was vital for improved student outcomes.

The problem of teachers' limited science knowledge continued to impact on their practice as they encountered difficulties in formative assessment: the 'what to notice', how to provide the next learning step, and understanding the

matrices. As a result progression in learning emerged as a significant problem. The researcher had concerns about the teachers' interpretation of the aspects and indicators, and the differences between the indicators over Levels<sup>14</sup>. The teachers' limited science understanding and, the lack of 'exemplars' to describe and exemplify the aspects made interpretation difficult. Teachers were asked to identify student learning against the indicators causing concern, in an attempt to clarify the meaning in relation to actual student work and behaviour. As teachers looked at the matrix indicators and identified individual students meeting these criteria they came to understand individual learning needs. A shift in teachers' pedagogy occurred as they became concerned with meeting the learning needs of individuals rather than whole class teaching, as had previously happened.

### *2D Reflection: Interviews*

The interviews became more reflective, with teachers sharing and analysing personal constructs and determining their next learning steps. The 'teacher as a learner' began to impact significantly on the teachers' practice.

### Engagement with the exemplars and matrix

Teachers' limited science knowledge and their pedagogy of teaching and learning in science were on going problems, although as they used the matrix, some aspects and indicators (such as Using Scientific Vocabulary) became tacit knowledge and as such teacher understanding developed.

(T4 int C2) *The matrix forces you to focus on the different things (communication, investigating, scientific ways of working and science in the wider world)...*

*It draws you into it so that's really useful. It takes you away from just knowledge.*

---

<sup>14</sup> Levels refer to the curriculum levels as defined in the Matrix.

The impact of unfamiliar contexts on student achievement emerged as an issue as teachers became more familiar with the matrices. Teachers came to understand the impact of prior knowledge on learning and, the usefulness of the indicators in identifying the students' next learning step. Using levels, rather than indicators to describe students' learning was unhelpful and unreliable.

(T2 int C2) *Last time they worked at Level Two vocabulary, but this time around because the context has been harder (students had little prior knowledge of the context) they are working mainly at Level One.*

Changes to notions about standards and expectations of achievement, for teachers and students, resulted in clearer identification of specific learning.

(T5 int C2) *If we see someone who is doing these things we are able to say – they have got a very good understanding of that concept because they can explain what they are thinking.*

### Pedagogy

As teachers' understanding of formative assessment developed, assessment was viewed as being more useful. Teachers increasingly used feedback to students to share how they were learning, how they were thinking and to encourage students to be 'risk-takers'. As teachers refined their practice and further developed their assessment knowledge, new issues emerged as being problematic: school-wide assessment of learning and school-wide data collection. These issues emerged as teachers came to appreciate that student achievement data was only useful if it could be responded to, in order to improve student learning, and showed a progression in learning.

Teachers' science pedagogy changed with teaching and learning becoming more co-constructivist and students engaging in more discourse. Teachers felt more accountable for student achievement and accepted they had to develop their own scientific knowledge:

(T1 int C2) *You have to know what you are teaching before you can get it across to the students. If you don't know yourself then you are not going to have the confidence to actually provide them with the right learning opportunities so that they get better learning as well. If you know the content not only can you meet the criteria (the matrix aspects and big ideas) but also you are far more flexible in how you approach it.*

### Teacher as a learner

In this second cycle, teachers began to reflect more deeply on their practice, why they did things and what they needed to change, and were able to identify personal areas for development. Teachers provided each other with considerable support and continued to share their practice and their students' achievement as they analysed student work and anecdotal information.

### Action research model

The researcher reflected on the interaction between the teachers and the researcher. The teachers conferred 'expert' status on the researcher and in order that teachers became 'participants' it was essential that this did not become a barrier. However as teachers' practice became subject to more scrutiny, coaching from a more knowledgeable peer or facilitator (the researcher) became vital to the development. An emerging issue was the importance of meeting regularly so that the researcher could provide support as the teachers struggled with trying to effect the changes, many of which were around teachers' science knowledge and pedagogy. The following comment is indicative of the change:

(T3 int C2) *It's been valuable having your input. We ran out of ideas and you helped us with the different learning activities that could build on our ideas.*

### *Summary of Cycle Two*

While teachers' knowledge of science developed through using the matrices and the exemplars, they continued to be constrained by their own limited science conceptual knowledge, limited constructivist pedagogies and limited formative assessment practice and knowledge. Nevertheless as some aspects became tacit knowledge teachers included more aspects in each unit of work, thus developing their knowledge, and the assessment focus moved beyond science concept knowledge.

Learning goals were more consistently shared with students and used as assessment criteria, with teachers providing feedback to students on their thinking and about changing their minds, thus identifying things of value for students. Planning continued to be a critical factor in the success of the science units. Emerged themes manifest themselves in new issues as teachers and students become more skilled and intent on refining their scientific understanding and practice.

### **Cycle Three**

#### *3A Planning for action*

The emerged theme of progression became more complex during Cycle Three as teachers considered the recording of student achievement against the matrix indicators and moderating students' work in order to develop reliable teacher judgements when using the indicators as assessment criteria. Teachers felt that in trying to cover all aspects, progression from one level to the next would be difficult, and raised the issue of whether some aspects were more significant than others. Although teachers expressed concerns about the matrix and the exemplars: some aspects contained too many ideas and were difficult to understand and some indicators (of an aspect) were similar across levels and therefore defining the next learning step was difficult, they did attribute changes in their practice to the use of the matrix, as illustrated in the following extract:

<p>(DNP1: 10) <i>The matrix is providing the breadth of science and an understanding of standards and expectations.</i></p>
---

Issues and concerns for the researcher were still largely centred on classroom practice: the alignment of teachers' assessment beliefs to practice, science conceptual understanding, the expectations and differences between levels, and strategies for developing students' thinking. As teachers' pedagogy developed they required more knowledge and support around thinking strategies to share with students, investigative skills and strategies, and more specifically fair-testing. They still needed support in developing their science conceptual knowledge and identifying appropriate learning activities in which to progress students' science understanding and thinking.

A change in emphasis in planning the units of work was evident: teachers now identified students' needs and the next learning steps before selecting the context of learning. Each learning intention was supported by a number of activities, thus providing more learning pathways and more opportunities to develop deeper understanding. As teachers began to understand that skills cannot be taught in one situation with the expectation that they will be automatically applied to another, the need for more student learning opportunities to facilitate the transfer of concepts and skills became apparent.

### *3B Observation of teacher participants*

As teachers' familiarity and understanding of the matrices developed, changes in their pedagogy and student outcomes became more evident. Teachers' assessment practice became more integrated into their teaching and field notes recorded more teachers using the matrix indicators as learning intentions, which they shared with students and referred to during discussions about learning. Feedback to students was around thinking, and not just knowledge. Teachers also showed themselves as learners to their students:

(T4, FN1: 62) Teacher: *I'm not sure either, but if we were thinking like a scientist how would we work?*

(T2, FN3: 34) Teacher: *We will refer back to our diagrams (before views) at the end of our unit and see whether we have changed our minds.*

As teachers used formative assessment data to shape learning, they provided a variety of strategies and opportunities for sharing knowledge. Teachers used assessment data formatively to make decisions about students' learning and the learning pathways:

(T4. FN1: 64) Teacher: *What have other people discovered?*

Students shared what they had done, all the time trying to determine whether the substances were alkaline, acids or carbonates and why they got the reaction they did. Students wanted to know why this had happened.

The teacher wrote up the students' question and 'parked' it to be referred to at a later stage. The students were happy that the question had not been ignored. The teachers' explanation, when asked why she had made that decision, was:

*It would have distracted from what we are learning. We need to keep to our learning intentions. We will return to it at the end of the unit, once we have reflected on what we have learned.*

Field notes over the cycles identified a number of changes to teachers' pedagogy. Students had more opportunities to engage in discourse with their peers, and readily challenged each other's ideas:

(T3. FN3: 26) New entrant students were independently drawing a diagram of sun and the earth. As they worked they talked about their drawings and challenged each other's ideas.

Student A: *You don't need to put all those bits around the sun.*

*The sun goes to the earth.*

Student B: *The sun is huge*

Student A: *That is not how you do it. You don't need all that stuff.*

*(Lines coming out from the sun).*

Student C: *It has a ring around it.*

Student C: *You forgot a ring around the sun.*

Student D: *You don't need one around the sun.*

Teachers also provided opportunities for students to model their ideas, thus helping to put abstract ideas into action. Teachers' talk became more explicit about the way scientists work and students were given more opportunities to carry out independent investigations and co-construct their understanding. For four teachers this was still a challenge, while for the other three it was accepted practice. The following excerpts demonstrate the differences in teachers' practice:

(T7. FN1: 76) Teacher: *Turn to the person next to you and talk about what is happening. Who will share what they thought, what you saw happening?*

Student: *It went bubbly when we put in the tartaric acid and the citric acid*

Teacher: *What did we learn today?*

Student A: *If you use heaps of substances that aren't acids we would have a bigger reaction.*

Teacher: *Perhaps we could look at changing the quantities Tomorrow and see whether you are right.*

A student commented: *we have done really well today because we put all the things in the right way – the right order and the right amount.*

(T4. FN1: 64) Teacher: *What reaction did you get?*

Student A: *It changed colour*

Teacher: *What else happened?*

Student A: *Nothing*

Teacher: *So what substances have we got here?*

Student A: *An acid and I don't know what the other one is.*

Teacher got the checklist of what happens when an acid and a carbonate and an alkaline and a carbonate are mixed.

Teacher: *Let's stop the class and see if they can help.*

*We have a question for good scientific brains.*

She explained what had happened and asked for ideas.

Student B: *They could both be carbonates*

Student C: *They could both be alkaline*

Teacher: *They are not powders so they can't be alkaline*

Student C: *O.K. They must be acids and you don't get a reaction.*

The teacher complimented the children on their scientific thinking.

Teacher T4 consistently used feedback to show students learning that was valued: students' thinking, being risk-takers, working scientifically and their concept development. She also modelled the 'teacher as a learner'.

### 3C *Intervention*

A significant trend emerged during this cycle. A growing familiarity with the matrix enabled teachers to describe student achievement in terms of the matrix "*aspects*" and "*indicators*" and provide the next-step learning, with links being made to other curriculum areas. Contexts of learning were selected to support learning needs identified by the matrices.

As teachers' knowledge and understanding of science concepts and constructivist teaching developed, they became more aware of the students' ideas and misconceptions and how these were at variance with scientists' ideas. These differences began to form the basis for discussion and investigation. As teachers became more focused on student achievement a number of new issues emerged. There was a growing awareness that students needed several opportunities in which to develop knowledge and skills and this placed considerable pressure on teachers as they endeavoured to find more activities or to modify the ones they already had. This was, in part, due to the ongoing theme of teachers' limited conceptual knowledge of the context.

Emerged themes became more complex, rather than being 'solved'. Students needed to model their understanding, the management of the students and the activities was difficult and grouping students so that optimum learning occurred for all students was challenging.

(T1 int C3) *The matrix indicators and aspects are more about what I need to be doing for the students, rather than what they need to be doing. I have to ask 'what am I going to be doing as a teacher to make sure these are met'.*

Interpretation of the aspects continued to be varied and one teacher's insistence that her level two students could be described by the level four indicators is an example of this. It also highlighted the danger of 'atomising' aspects for the purpose of progression, rather than viewing all of the aspects within a level as being interdependent and contributing to understanding in science.

Developing a progression of learning around worthwhile goals was raised as an issue by the researcher. Teachers decided the aspects, such as "*Using Scientific Vocabulary*", which had become tacit knowledge and were now inherent in the way they taught, were not appropriate. Other aspects, for example "*reporting*", were considered to be worthy of progression.

### 3D *Reflection: Interviews*

The same trends continued to emerge from the individual interviews, albeit they became more complex as teachers refined their practice.

#### Engagement with the exemplars and matrix

The exemplars and associated matrix influenced teachers' practice and the way they viewed science teaching and learning and their expectations they held for their students:

(T7 int C3) *We would have got the activities around levels two and three and done them.*

*We never would have thought – what things can they do and what is the next-step.*

*Now we look (at the matrix) and think the students are here, what do we have to do to get them to the next step.*

#### Assessment knowledge and pedagogy

Teachers' ability to ascertain worthwhile goals, establish 'reliability' in the way they understood and interpreted indicators, moderate and establish standards

and expectations of student achievement, continued to be hindered by their limited science and assessment knowledge. Even so, change did occur:

(T4 int C3) *We are developing inquiring minds - they have the skills now to ask questions and to test their questions and predictions. They're just about able to learn independently. You need to revisit activities and let the students try different combinations of their ideas and theories so that they learn in-depth. They see patterns and relationships more clearly because it is Happening again and again. But they see variations and say 'oh what is happening here? Why is that happening? They can do something about it.*

Teachers began to identify goals for progression from unit to unit around student needs. Still, the issues of school-wide data collection and progression continued to challenge teachers as they tried to determine key aspects as worthwhile learning goals in which to effect a progression.

(T1 int C3) *We need to know what the children will need at the next level – that's the school-wide thing. It's not so much the content but the skills of how to learn it (the science content) and what learning is.*

### Pedagogy

The matrix provided teachers and students with a more comprehensive view of science. As a result teaching strategies changed, teachers shared the learning with the students, co-constructed ideas and understandings with them, and provided opportunities for the students to carry out their own investigations. Focused, organised and explicit planning allowed teachers to engage in more deliberate acts of teaching.

### Teacher as a learner

The importance of working collaboratively and having open discussions was expressed by all of the teachers:

(T2 int C3) *Helping each other has really enriched our programmes, instead of putting things in the too hard basket we are challenging ourselves and it is impacting on the children.*

The teachers' attitude to the action research study was instrumental to its success. Teachers were totally committed to improving their practice and the achievement of their students and the following comment is characteristic of all the teachers:

(T6 int C3) *What has changed for me is my enthusiasm and willingness to give science a go. The fact is I know that I am going to make a difference for those children and that for me is the bottom line. If I am going to make a difference for the kids then I will try anything.*

(T5 int C3) *I've thought it through (the lesson) and I think that is a big thing. It's good; I mean I'm only growing. I don't like it but it has actually done me the world of good - especially because I have been teaching for such a long time.*

#### Action research model

As teachers saw the improved outcomes for students they began to value the observations and the feedback on their practice. Teachers were far more reflective, they confronted old assumptions about teaching and learning and new ones about participation of students. The discussion and support became more specific and detailed. The following excerpts illustrate the value of reflection and coaching, as well as the need for researchers to be empathetic and to form relationships built on trust and respect:

(T6 int C3) *It's almost the ultimate of teaching to have someone with the knowledge able to come in and share, but allow people to learn. Which is what we are doing. But you have to have the right people.*

(T4 int C3) *The meetings after the observations have been useful because we have had to reflect and think about where we are going to go next.*

*And to have someone asking the questions, to point you in the right direction is really useful. I really like this model (action research) and I think the in-class observations and support, even though it is uncomfortable, is definitely worthwhile. It's the professional input and how often do you get a chance to discuss something in your room.*

### *Summary of Cycle Three*

Assessment emerged as a significant theme and became more complex as teachers' knowledge and practice developed. Teachers began to focus on school-wide issues of assessment: what data to collect and how to make assessment of matrices aspects and indicators more manageable. Teachers continued to have detailed 'head notes'<sup>15</sup> and in fact made no change to assessment practice in terms of collecting and recording data.

Students' needs were determined by good assessment practice and teachers' increased knowledge of science began to shape learning opportunities. As a result, student outcomes changed, with deeper learning occurring as students worked in more constructivist and scientific ways. Students were increasingly reflecting on their learning and were more empowered to think and learn for themselves. Each classroom was developing as a learning community and teachers were promoting particular learning attitudes of open-mindedness and being responsible risk-takers.

---

<sup>15</sup> Head notes are the information and ideas teachers' hold in their heads about students' achievement.

## Cycle Four

### 4A *Planning for action*

The two teachers from School B who continued into Cycle Four, identified progression in student learning as being critical. Interpretation and the differences in meaning between the indicators and aspects emerged as being problematic because of the teachers' limited science understanding. In order to continue building knowledge of the matrices, teachers revisited them, identifying the learning students brought to the new unit, and the gaps that still existed. Matrix indicators and aspects provided the assessment criteria and the foci were: "*investigating, collecting data in a systematic way*" and "*explaining and justifying ideas*". Discussion around these aspects was essential to clarify teachers' thinking and understanding.

As teachers and students learned to work in a constructivist way further issues emerged: students needed a number of skills in order to be able to investigate and they also needed teachers to provide the opportunity for them to work independently, scientifically and systematically. Teachers were challenged to 'exploit' learning opportunities so that multi-faceted learning (reflecting on learning, metacognition, taking individual needs into account) occurred. While the planning had become accepted practice, teachers still needed support in identifying worthwhile learning goals and in developing their understanding of the science concepts.

### 4B *Observation of teacher participants*

Field notes revealed that over the past three cycles students had developed significant investigating skills of "*exploring a situation, collecting data systematically, making predictions*" and "*asking questions*" and were now expected to *process and interpret* their data. Aspects and indicators previously developed were now part of the teachers' and students' discourse and influenced the way they worked, but the teachers' lack of conceptual understanding did at times influence the questions and constrain the thinking and learning, as illustrated by the following extracts:

(T1. FN3: 75) Teacher (to five and six year old students): *We have some wonderful mixtures. We have started off with a powder and a liquid and we now have some very interesting substances. What has happened? Are some substances a powder or are they liquids? What else have you found out?*

Student A: *We have something that is not a powder and it is not a liquid. But we don't know what it is.*

Teacher: *Can you describe it?*

Student B: *It is hard but it is a liquid.*

Teacher: *Where did the powder go?*

Student C: *The powder went into the water so we don't have any more powder left.*

Student D: *We have some hard bits that are in a liquid. It isn't a powder any longer.*

(T2. FN3: 77) Teacher: *Before you mix the substances I want you to think about their physical properties. I then want you think about what might happen to the physical properties when you mix two substances together. You will then need to record your prediction.*

Student: *Some substances might not mix. They might stay the same.*

Teacher: *Can you explain that a bit more?*

Student: *The two colours might not mix, they might stay the same.*

These students were six and seven years old.

Progression in learning continued to be a problem. However as the teachers decided to develop a progression across aspects within a matrix, rather than atomising one aspect and trying to develop a progression from level one to level three, they came to understand how the aspects in the matrix were related to each other and not independent entities. For example in order for students to “*process and interpret*” data they need to have “*explored a situation*” and collected data “*systematically*”, using “*scientific conventions*”.

Observations revealed that teachers’ assessment knowledge and practice had become much more integrated. Students and teachers worked more in partnership and students contributed to learning intentions and success criteria.

Students began to accept more responsibility for their learning, were more motivated and the changes in student learning were significant, as were the changes in the teachers' pedagogy. While much of the learning had been around science conceptual understanding at the outset of the research project, learning in Cycle Four was evidenced in the way students worked scientifically. Students were given more independence in setting up and managing their investigation and were expected to use the whole investigative process. The following excerpt illustrates the way the year two (six year old) students worked:

(T1. FN3: 73) Students were very intent on carrying out their investigations and recording their data, especially making the predictions and finding out whether they were correct. All information was carefully recorded on the following sheet:

<b>Mix</b>	<b>We think / Predict</b>	<b>We Notice</b>	<b>X <math>\checkmark</math></b>

Teacher: *L can you share with us what you found out?*

Student: *We mixed D and oil.*

Teacher: *What did you predict would happen?*

Student: *It would be icy and bumpy.*

Teacher: *What do you mean by icy?*

Student: *It would be white.*

Teacher: *Did you think it would be cold if it were white?*

Student: *Yes.*

Students were encouraged to relate new knowledge to what they already knew. Teachers scaffolded the learning in ways that best facilitated the development of the students' understanding. As students became more cognisant of learning goals and reflecting on their learning, they readily shared their ideas. Students now had the skills to carry out independent group investigations. Teachers modelled the investigative process so that students were able to record their data systematically, use scientific vocabulary and work as 'scientists':

(T2. FN3: 83) The teacher reminded the students of how to carry out an investigation and what they would need to think about:

- *Remember we are mixing a solid and a liquid.*
- *When you are predicting you will need to think about the physical properties of the substances. Make sure you write down your prediction before you start.*
- *You will need to look carefully to see if there is a change in texture, colour, smell, solid or liquid.*
- *Remember how to measure, and how to keep things fair.*

The equipment was set out for the children, they were put into groups and then they organised the group tasks and how to manage the investigation.

Every student was intent on the investigation and made sure they worked "*like scientists*", the criteria for which had been established over previous learning opportunities and modelled by the teacher.

- They measured carefully and all checked it was correct
- They collected data systematically and recorded everything
- Students challenged each other to provide explanations
- They were able to talk about their predictions
- They were able to use words to describe the physical properties of substances
- They kept their equipment and workspace clean

As students worked independently teachers moved around the room asking questions of students and challenging their thinking. A significant change in practice occurred for Teacher 2, who had strongly felt the students could not independently investigate.

#### 4C *Intervention*

Growing familiarity with the matrices allowed teachers to more 'scientifically' describe their students' achievement and identify the next learning step for students. Teachers were amazed at the achievement and engagement of their

students, the considerable changes to their own teaching practice, and the depth of knowledge about 'science' for both them and their students.

As teachers' science pedagogy developed, new issues emerged. Teachers wanted students to investigate 'flawlessly'. They did not see as valid students reflecting on their investigative process, identifying how to improve it and then carrying out further trials. Moreover the teachers saw the management of the investigative activities as being problematic. They also saw the collecting of individual student data in 'investigating' situations as problematic.

The ongoing theme of teachers' limited conceptual knowledge continued to raise issues of: the conceptual pathway of the science ideas, the need for more activities in which to develop students' understanding of science concepts, and how to provide individual students with the next learning steps.

The problem of teachers' pedagogical knowledge changed as their practice developed. Teachers were now more concerned with the theoretical underpinnings of the nature and purpose of investigating, the validity of allowing students to investigate independently, the way learning and meaning takes place, ownership of learning, and conceptual understanding in science. Professional reading and discussion around these points was necessary. Understanding formative assessment, and a commitment to raising students' achievement, focused the teachers on identifying the differences between the indicators and aspects. A need to develop further formative assessment strategies became apparent to the teachers and the researcher.

#### *4D Reflection: Interviews*

The trends that had emerged in previous cycles were on-going, but the teacher as a learner became more significant as the two teachers took more risks with their practice, and trialled new strategies and ways of working.

### Engagement with the exemplars and matrix

Another issue was raised, that of implementation. All teachers felt that without support, teachers would not use the exemplars and matrix with understanding and their use would not be sustained.

(T2 int C4) *If teachers were just given the matrix I don't think they would be able to use it as effectively if they did not have the support the way we have.*

### Assessment knowledge and pedagogy

Teachers' notions of progression over year levels developed but continued to be a problem as teachers grappled with what progression was and how it impacted on them. Progression was seen at a classroom level and a school-wide level:

(T1 int C4) *The long-term overview is important so that children can have experience in all aspects. For juniors some have to be scaffolded really carefully. Some [aspects] they need to learn before others... We need to build on aspects and indicators school-wide. The older children need to deal with the more complex ones.*

While teachers were adamant that progression should occur, the decisions about worthwhile goals on which to base progression, and its management, proved difficult and requires further thought and research.

### Pedagogy

Teachers were able to identify individual achievement, determine learning pathways and provide learning opportunities for students, including students' with diverse needs:

T1 int C4) B *(a special needs student) has managed to do all of this (science). He has loved it. And at the same time I can challenge the more able children by asking them questions and providing different challenges for them. Just pushing them that bit further.*

Outcomes for students changed over the four cycles. Students were working in a more co-constructivist way, had a better understanding of the nature of science and the way in which they themselves learned. Student achievement was raised, as students knew the learning goals and how to achieve them:

(T2 int C4) *I've been trying to stand back and give them more independence... they have loved having ownership of their investigating - setting them up themselves and making choices.*

(T1 int C4) *Students not only have the knowledge but they are aware of the differences in their thinking as well.*

Planning was identified by the teacher participants as being fundamental to success, as learning goals and learning pathways were clearly identified, and teachers took responsibility for developing their scientific knowledge. The following excerpt illustrates the changes to teachers' practice and thinking:

(T1 int C4) *As the year has gone on they (students) have got better at explaining their learning... to me it's the big link between 'what we are learning, what we already know and what we need to find out.'*

### Teacher as a learner

Over the four cycles the two themes of the action research model and the teacher as a learner were influential in the success of this action research project. The teachers identified as being significant: working collaboratively, having a commitment to the development, reflecting on their practice, and the support of an outside facilitator. The following excerpts demonstrate the themes:

(T1 int C4) *We have developed a strong professional dialogue amongst our team. There is a culture that has been established of absolute honesty of what works and what doesn't. We have helped each other. There have been no barriers and we have just wanted to get into it. The whole team involvement has been really important.*

Teachers valued the opportunity to reflect on their practice and their learning and to be able to articulate their learning. When they did this as learners they were able to simultaneously facilitate the same learning process for their students.

(T2 int C4) *The self-reflecting has been really positive. Without the interviews I don't think that (self-reflecting) would have happened...The meetings after school were really good as we could discuss things if we got stuck otherwise we might have given up.*

(T1 int C4) *You have scaffolded us in learning how to use the science exemplars and the matrix and putting in the science ideas so that we've grown like the kids have grown in their learning. So you have modeled exactly for us as teachers what we should be doing with the children. I think that has been huge.*

#### *Summary of Cycle Four*

Teachers and students developed a greater awareness and understanding of science and the teaching and learning of it. Teachers considered the planning as being a vital factor in the success of the development. The teachers identified worthwhile learning goals, and how to recognise and achieve the goals. In raising student achievement, the enthusiasm and confidence of both themselves and their students improved greatly. Students constructed their own understandings as teachers challenged their students' thinking and ideas, and allowed them to trial, explore and engage in discourse. Students had clear expectations and support to achieve learning goals and become independent learners. Teachers accepted responsibility for effective teaching and learning in

science, and identified their own knowledge as being critical to the students' achievement:

(T1 int C4) *My knowledge has made the biggest difference to the students' achievement. Also the planning, thinking things through, knowing where you are headed and what you want to achieve.*

### **Chapter summary**

Two problems emerged as being foundational to the research study: teachers' limited science knowledge and pedagogy, and, teachers' limited formative assessment practice and knowledge. These continued to iterate through the four cycles. Changes to the teachers' expectations of student achievement, developed through the National Exemplars and associated Matrix, were instrumental in motivating the teachers to reflect on their practice and to make the changes that resulted in improved outcomes and achievement in science for their students. Teacher and student questioning improved, students more independently carried out investigations and teachers focused on student learning rather than activities per se. A more comprehensive understanding of the nature of science, science conceptual knowledge, science pedagogies and formative assessment practices appropriate to effective science teaching and learning were developed. The teacher as a learner and the nature of the professional development/action research model significantly influenced these understandings.

Chapter Five, the Discussion, will consider these changes, the factors that impacted on their development and links to the literature.

## **CHAPTER 5: Discussion**

### **Introduction**

This research study set out to investigate the impact of the National Exemplars and associated Matrix on teaching and learning in science. The seven teacher participants in the study were teachers of five to nine year olds, with the major cohort of students falling into the six and seven year old group. Therefore changes to teaching and learning in science are viewed and interpreted through that lens. This chapter revisits the literature reviewed in Chapter Two and the data and the emerging themes presented in Chapter Four. Drawing these together, the study identifies, with theoretical underpinnings, the changes to teaching and learning in science and the issues and factors that impact on the changes, as a result of the teacher participants interacting with the National Science Exemplars and Matrix.

The researcher argues that the National Science Exemplars and Matrix provide a framework which identify and describe the important goals of science, signal “educationally significant learning progressions and clarified curriculum expectations and standards” (Chamberlain, 2000, p. 3), provide the focus for dialogue and professional development and, as a consequence, impact on teaching and learning in science. In interacting with the exemplars and matrix two problems which restricted the teachers’ understanding and use of the exemplars and matrix were revealed: firstly the teachers’ limited science conceptual knowledge, science pedagogy and knowledge of the nature of science, and secondly the teachers’ confused notions of formative assessment practices and more specifically progression in science. The researcher contends that fundamental to addressing these problems, was the nature of the action research model and the ‘teacher as a learner’.

### **Science teaching and learning: Putting new theory into practice**

The teacher participants in this research study, like most primary school teachers (Harlen, 2000), had little understanding of the nature of science

and as a consequence this impacted on the way they taught science in their classrooms. In viewing science teaching to be the 'telling' and learning of 'scientific truths' (Carr et al., 1994) teachers covered science concepts which were 'told' to students with little opportunity for them to engage in deep learning (Entwistle, 1992, cited by Gipps, 1999).

The matrix, in providing a broad framework for teaching and learning in science, was instrumental in raising the teachers' awareness of the nature of science and identifying for them additional worthwhile goals of science: investigating in science, the way scientists work and think, communicating scientifically and the way in which the work of scientists interacts with society. As a result of the teachers' growing awareness and understanding of the nature of science, developed through using the exemplars and matrix, changes to the teachers' pedagogy were effected. As teachers endeavoured to provide opportunities for students to work, think and communicate their understandings in scientific ways, the teachers identified a need for teaching strategies that would cause learning to occur. Constructivist theory underpinned the changes to the teachers' science pedagogies.

#### *Co-constructivism*

Co-constructivist theory purports that any significant change that occurs in learning, happens in the head of the students and therefore students must play an active role in 'constructing' their own meaning (von Glaserfeld, 1990). In order to realise this, the teachers increasingly provided the opportunities and the expectation that students would share, explain and justify their ideas, and negotiate meaning, thus supporting the claims of Prawat (1993, cited in Treagust et al., 1996) that through discussion meaning is constructed. Some students began to have the same expectations of their peers when they worked collaboratively and, as Sadler (1987) states, learned by taking on the role of teachers and examiners of others. The teachers also found that in working collaboratively, students were able to give and receive elaborated explanations, thus constructing their own understanding and challenging the ideas of others (Sadler, 1987;

Resnick, 1989, cited in Gipps, 1999). Increasingly teachers made more provision for students to engage in group work, rather than participating in whole class or individual activities, and found that in working collaboratively the tasks became the responsibility of the whole group and reduced the possibility of failure (Sadler, 1987).

The expectation that the students would work collaboratively required additional skills that teachers had to attend to before the students were able to work effectively in this way. Students had to learn to work co-operatively and, especially for the youngest students, learn to take turns and to listen to each other. In grouping students so they could work collaboratively two issues were raised: should the groups be mixed ability so that the older and or more able students could guide the other students and record the groups' ideas, or should the more able students be put together so that they could challenge and extend each other's understanding? Thus highlighting the dilemma of whether teachers should be concerned with the management or the cognitive engagement of students (Windschilt, 2002, cited in Le Cornu & Peters, 2005). In response one teacher set an individual goal of trialling different grouping and management strategies, and monitoring the changes in students' achievement and engagement.

The need to develop teaching strategies that allowed for individual children to be challenged and supported in their learning became evident as teachers became more aware of students' learning and saw the students as individuals.

(T4 int C3) *The matrix criteria have been broken down to such a stage where you have to think about the individuals. You cannot use it to judge the whole class. It supports more individual type work.*

In order to support individual students' learning, teachers had to access the students' ideas. The teachers provided their students with opportunities for the declaration of existing ideas, through dialogue and through writing down their ideas; the consideration of other ideas (both other students' and

scientists' ideas) to see whether they made more sense; and the opportunity to change their minds as they co-constructed meaning. As Jenlick (1996, cited in Le Cornu & Peters, 2005) states, learning is a process of accommodation or adaptation, based on new experiences and ideas.

While some conflict exists as to the purpose and usefulness of eliciting students' ideas prior to beginning learning experiences in science (Asoko, 2002), eliciting students' prior knowledge was an enlightening activity for five of the teacher participants, as they had previously not considered what their students might already know. In gaining an awareness of the differing views their students held, the teachers came to understand the complexities of teaching science. Teachers were also led into examining their own science concepts and in some instances shared the misconceptions that their students held.

Over the research cycles the teachers came to appreciate that it was not just the students' ideas alone that were important but the differences between their ideas and the science ideas to be taught (Hewson, 1991, cited in Stahly, Krockover & Shepardson, 1999; Watts, 1994; Novak et al., 2000; Davies, A, 2000). For three teachers this changed the context and structure of learning opportunities so that they provoked discussion and debate rather than assigning pre-determined activities to deal with students' questions (Ritchie, 1998).

(T1. FN2: 53) *I need to create a gap in their ideas so that we have a pathway forward. I want them to prove or disprove ideas.*

Moreover, in order to create 'gaps', teachers had to ensure that their own scientific understandings were sufficient to challenge the students, present other conflicting ideas and scaffold the students' learning as they constructed new understandings. As stated by Harlen (2000) and Black and William (2000), teachers need a thorough understanding of the fundamental principles of a subject if they are to cause thinking to occur, and to this end the teacher participants undertook professional reading and professional

development supported by the researcher. They grew to rely on each other as they pooled their knowledge and accepted responsibility for finding the knowledge they needed. In developing this 'community of learners' the teachers were putting into practice the principles of participatory action research, which aim to improve understanding and practice and the situations in which the participants function through collaboration and critique of their practice.

In order to develop a deep understanding of science concepts, Ogborn, Kress, Martins and McGillicuddy (1996, cited by Asoko, 2002) assert teachers have to give abstract ideas some form of physical reality to 'talk them into existence'. The teachers effected this by providing students with opportunities to model their understanding.

(T3. FN3: 40) Teacher: *Who would like to have the first turn to show us what happens? What will the sun be doing?*  
 Student A: *Staying still.*  
 Teacher: *What will the earth do?*  
 Student B: *The earth is going to go around the sun.*  
 Student C: *I don't think that is quite right.*  
 Teacher: *O. K. who wants to have a turn?*  
*Does the earth go around the sun that fast?*  
 Students modeling the earth spinning.  
 Teacher: *Stop. Is it day or night?*  
 Student E: *It is night.*

Teachers also focused on finding ways to introduce and explain useful and relevant ideas at appropriate times and in ways that made sense to their students. As Sutton (1992, cited in Sprod, 1998) asserts, practical experience does not itself bring about learning until it is animated by ideas. This was difficult for teachers who were skilled at organising and managing, but not skilled in strategies for managing students' intellectual engagement in science (Windschilt, 2002, cited in Le Cornu & Peters, 2005). Explanation

and challenging students' ideas is much more than 'telling', and difficult for teachers if they do not have the science knowledge.

In changing from being the 'tellers' of information to being concerned with students constructing understanding, the teachers became facilitators of student learning and therefore concerned with the management of learning and learning opportunities. Teachers provided opportunities for students to model, collaborate and reflect on their learning and as a consequence students engaged in more discourse.

### *Discourse*

The teacher participants in providing more opportunities for students to engage in discourse found discourse also improves thinking and develops reasoning skills. As Lawson (1990) asserts, reflective reasoners are more likely to change conceptions under instruction and as a result students' ideas can be socially mediated. Prawat (1993, cited by Ritchie, 1998) states, it is through socially mediating ideas that students have their ideas challenged by their peers and others and sometimes it is only then that students become aware that other people hold different ideas. As Crooks (1988) claims, students are often more accepting of criticism from their peers. As a consequence, teachers phrased talk around learning, moved from whole class interaction to groups, with pairs talking about ideas and then sharing them collectively. The importance of questioning skills in facilitating students' thinking and understanding quickly became evident.

### *Questioning*

Phrasing a question requires a detailed knowledge of the context, an understanding of the difficulties that students might have in constructing meaning (Asoko, 2002) and the creativity to construct questions that would stimulate productive thinking (Black and Wiliam, 2000). The teachers' questions improved significantly over the cycles of action research as they became more comfortable and knowledgeable about co-constructivist

teaching and developed their own science knowledge. Questions changed from merely eliciting students' ideas (surface learning<sup>16</sup>) to being more probing and thus extending students' thinking (deep learning), thereby utilizing Vygotsky's (1992, cited by Gipps, 1999) notion of scaffolding.

Teachers used the matrix indicators to help them frame questions, challenge and extend students, and cause thinking to occur, as their students constructed meaning from their experiences and ideas. Thus, growth in teachers' questioning skills was directly attributable to the matrix and exemplars:

(T6 int C1)      *I have the matrix on my knee when I am talking to the children. Then when I get stuck I can look at it and think "oh yes that is what I am trying to do".*

### *Planning*

The teachers identified planning as being a significant factor in the success of the action research study. The planning (see Appendix 7), with its identified learning goals and criteria for success, caused teachers to be focused and knowledgeable about what they taught and about what students' constructed meaning. Teachers were then able to ask more effective questions. This finding is supported by Vygotsky (1992, cited by Gipps, 2001), Cavalcante, Newton and Newton (1997, cited in Asoko, 2002), Clarke (2001), and Black and Wiliam (2002) and Clarke et al. (2003), who state lessons that introduce a conceptual structure, that is are scaffolded, are more effective in causing students to think and understand.

As the teachers put into practice the principles of co-constructivism they became critically conscious of the dynamics of their classroom culture, classroom management and the patterns of classroom discourse, as well as the thinking and learning within them (Windschilt, 2002, cited in Le Cornu & Peters, 2005). Therefore, the focus in planning units of work moved from identifying learning goals, success criteria and supporting activities to

---

<sup>16</sup> Surface learning: rote learning and memorization of facts.

discussing the best teaching strategies to use and how learning opportunities could be best exploited to allow learning to occur.

Teachers narrowed their teaching focus and the number of concepts they wished the students to 'learn' and began to appreciate that depth of understanding, and not coverage of a number of learning goals, was important for deep learning. Brown, Collins and Duguid (1995, cited in Bell & Baker, 1997) and Prawat (1993, cited in Ritchie, 1998) argue that the more a concept is used, the more it will be recast and understood in a more densely textured form and as such has implications for planning learning opportunities. In narrowing the contexts of learning, teachers also developed their understanding of science in a deeper and more flexible way, which allowed them, as Hattie (2002, p. 22) asserts, "to organize and adapt knowledge structures to the diverse interests and abilities of their particular students". The teachers were able to engage in more explicit acts of teaching.

### *Children investigating*

The students' participation and skill in investigating was evidence of their teachers' changing pedagogy and understanding of science. The teachers had held a view of 'investigating', usually developed through their own science experiences, that tended to see investigating as a research model<sup>17</sup> or a fair-testing model where results were almost predetermined and proved the science 'truths' (Watts, 1994). They therefore had deemed investigating to be unsuitable for young students (five to nine year olds).

The teachers, in developing their own understanding of investigating in science through using the framework in the "*Investigating in Science*" (Matrix B), changed their students' understanding and achievement in investigating so that students were able to independently carry out simple trials, systematically collect data and explain and interpret their results. Through collaboratively carrying out investigations, students were able to construct

---

<sup>17</sup> Research Model: Information gained from books or talking to people, and therefore a secondhand experience.

conceptual understandings through negotiating meaning with their peers and teachers (Watts, 1994).

### **Interacting with the exemplars and matrix**

While it could be argued that the changes to teachers' practice and understandings could be achieved through professional development and discussion about co-constructivist teaching, the teachers and the researcher believe that the matrix and the exemplars were fundamental to raising teachers' awareness of teaching and learning in science. The exemplars and the matrix also provided a framework (Dufour, 2004) around which to base professional discussions, which in turn identified specific professional development needs such as the development of teachers' science conceptual knowledge.

#### *The matrix*

The matrix raised teachers' awareness of the nature of science, identified for them additional worthwhile goals of science, and provided the teachers with expectations for the way science could be taught and learned. The matrix aspects were at times the learning goals, such as "*making predictions*" and "*asking questions*" (Matrix B: Investigating in Science), while at other times they were inherent in the activities provided and informed the way the learning activity could be structured, such as "*reflecting on their understanding*" and "*using quantitative ideas*" (Matrix D: Developing and Communicating Scientific Understanding). However, while some of the aspects were inherent in the activities, that is they provided a pedagogical function, they could also be shared with the students as learning goals (intentions) and formatively assessed (Black & Wiliam, 1998; Gipps, 1999; Harlen, 2000; Clarke, 2001; Clarke et al., 2003).

(T1 int C3)

*The matrix aspects and indicators have become a 'generating' influence for how you 'do' the teaching.*

Teachers could see how ideas were linked and interdependent within and across matrices. For example, students do not carry out “*simple trials*” without “*having a question*” to answer, “*an idea of what might happen*”, “*carrying out observations*” and “*collecting data*” (Matrix B: Investigating in Science). In “*explaining their ideas*”, students need to have the appropriate “*science vocabulary*” (Matrix D: Developing and communicating Scientific Understanding). The matrix, supported by the exemplars, provided the teachers with manageable learning pathways (Sadler, 1989; Harlen, 2000; Clarke, 2001; Black & William, 2002; Huinker & Freckmann, 2004). Initially the teachers were concerned that an assessment focus on learning goals other than knowledge would be harmful to students’ science knowledge. This proved to be unfounded and teachers soon insisted, and were supported by student work and researcher observations, that the students’ conceptual knowledge had improved.

The teachers floundered in trying to develop a progression of learning and determine the long-term goals of science, especially those to be addressed school-wide. In learning to use and understand the matrix aspects and indicators, the teachers had focused on one or two aspects at a time. In atomising the matrix in this way, they then had difficulty in seeing the aspects as part of a whole. Teachers had at first thought they needed to progress their students within an aspect from level to level, and it was only with intensive discussion and further understanding that they began to see that all of the aspects contributed to the notion of ‘science’. The ‘overall progressions’ in each matrix were too global for the teachers to understand and as a result were not useful as assessment criteria, or learning goals.

Teachers changed from selecting aspects from the matrix that looked reasonably familiar or achievable to selecting aspects and indicators that they identified as being ‘gaps’ in their students’ learning. As a result the matrix indicators and aspects drove the teaching and learning, and contexts of learning were selected to support the identified needs. This was also indicative of a change to teachers’ thinking about the matrices. At first they had considered that the aspects and indicators were to be ‘covered’ and had

not appreciated their value in describing students' learning and identifying pathways for progression in learning.

As the teachers' confidence grew, they became more intent on improving the learning outcomes for students and began to consider more aspects and indicators from the matrix, which then caused them to view science teaching from a more constructivist perspective. Although the teachers' knowledge of science developed, the pathway was not without frustrations. Some matrix aspects and indicators are context dependent and not the generalised skills or processes that the teachers had originally thought. This supports the view of Resnick (1987, cited in Gipps, 1999) and Gipps (1999) that skills and knowledge are known to be dependent on the context in which they are learnt and practiced, and transfer to another situation is not guaranteed. Rogoff and Lave (1988, cited in Hennessy, 1993) also claim that thinking is not only context based but is also situation specific. Therefore in order for students to transfer knowledge and skills from one context, or situation, to another, the learning has to be scaffolded (Vygotsky, 1992, cited by Gipps, 1999) by the teacher, with comparisons being made, similarities and differences identified and a decision made about whether the knowledge or skills are useful in a new situation. As a consequence, the teachers found that some of their understandings of the matrix aspects and indicators had to be renegotiated as they and their students worked in different contexts.

Considerable support and debate in using and understanding the matrix was necessary as many of the indicators were difficult to interpret and appeared to be very similar. As teachers became more familiar with the matrix, some aspects and indicators became tacit knowledge and caused the teachers to view the matrix as being more manageable. Teachers felt that the matrices were more helpful for teaching than assessment purposes. Paradoxically, when the researcher asked the participants to describe their students' learning, they did so using the aspects and indicators, from the matrix, as criteria. The teachers also identified the need to be very clear about the next learning steps, as described in the matrix, in order to progress their students' learning:

(T1 int C3) *I need to know in my head what Level 1 looks like and Level 2 looks like so that I can move them on (the students), especially the bright little ones.*

Many of the teachers reported that they had 'only kept anecdotal notes' and not done any proper assessment. These notions would suggest that the teachers still have a confused idea of the role of assessment in effective teaching and learning.

### *The exemplars*

The exemplars initially provided the teachers with teaching strategies and activities, science conceptual knowledge, models of questioning and discourse and the next steps in the students' learning. As Sadler (1987); Gipps (1999); Harlen (2000) and Black and Wiliam (2002) argue, concrete examples should be provided as models that denote standards for achievement. The teachers became aware of the gap between the expectations of achievement and standards held nationally, and their own expectations of their students' achievement.

Lezotte (1990, cited by Timperly, 2003) and Good and Brophy (1997, cited by Timperly, 2003) argue that teachers' expectations influence student achievement as the beliefs teachers have about their students' academic potential become the goals for their students and shape their daily classroom actions, including what they believe to be appropriate curriculum goals. This is evident in the following excerpt:

(T5 int C1) *I have under estimated kids ability at this age, to cope with the scientific vocabulary and the thinking... I looked at the exemplar and I saw what they thought was a good example (of student work) and I looked at the questions and I thought I have sold these kids short.  
We need to go back and start again and raise our expectations.*

In developing their own science knowledge and pedagogy to meet the identified standards, teachers raised their students' achievement in science thus supporting the view of Alton-Lee (2002) and Timperley (2003), that by being presented with information that is discrepant with their existing ideas about student capability, teachers' beliefs on the impact of teaching and learning can be challenged, through the critique of their own practice. While the teachers initially compared their students' work to the samples of work in the exemplars, over the action research cycles they became less concerned with the exemplars as their own science knowledge and understanding developed, thus supporting Gipps' (1999) notion that teachers' knowledge and understanding can develop through the use of exemplars.

(T2 int C4)      *As we have become more confident in using the matrix by ourselves...*

*We have developed an idea of what the levels might look like and we have not used the exemplars.*

Not all aspects and indicators are exemplified in the exemplars and teachers had to make their own judgements about the meaning of some of the aspects and indicators, and the differences between them. As a result the teachers' confidence in their own professional judgement developed. The teachers elected to moderate student's work against examples developed within their syndicate and raised the notion of moderating work against the student work of the other research school, in order to establish comparability (Sadler, 1989) in the way they interpreted the matrix, and to develop a more comprehensive notion of standards.

The exemplars and matrix provided teachers with worthwhile learning goals of science, provided learning pathways for students, raised the teachers' expectations and standards and in so doing raised their students' achievement in science. As teachers' understanding of science developed, so too did their pedagogical skills and understanding.

## **Considering teacher change**

This next section considers the two problems that restricted the teachers' use and understanding of the exemplars and matrix: the teachers' knowledge of science, and the teachers' formative assessment practice. Factors that were instrumental in addressing the identified problems will also be discussed.

## **Major themes to emerge**

### *Teachers' knowledge of science*

The teacher participants' restricted conceptual knowledge, science pedagogy and knowledge of the nature of science impacted critically on their understanding of science, the expectations they had for their students and the professional development itself. It also accounted for, in part, the variations in the teachers' performance. Some of the teacher participants, in their previous science teaching, had avoided practical work or 'real experiences', limited their students to research based investigations, 'told' the students the science, avoided equipment or activities that might go wrong, and minimized students' opportunities to ask questions and find answers through exploration. Teachers initially had difficulty in probing students' thinking, eliciting the students' ideas, challenging the students' ideas, and in providing alternative views for students to consider. Harlen and James (1996, cited in Harlen, 2000); Black and Wiliam (2000), Guskey (2000) and Cohen and Hill (2000, cited in Ingvarson, 2005) agree that without sufficient pedagogical skills and content knowledge, teachers limit students to impoverished and restricted learning opportunities.

As teachers' conceptual knowledge and understanding of the nature of science developed through the matrices, they became aware of the difference this made to their students. Learning activities need to be continually adjusted in the light of formative assessment data, and while the teachers recognized this they were not always able to do so because of the limitations of their own conceptual knowledge. As stated by Segall (2004), deeper knowledge of content helps teachers select the best explanations

and examples, and the most appropriate methods and techniques through which to engage students with content.

(T4 int C3) *A change of attitude would be one of the biggest changes for the children. They are thinking like scientists and their whole interest in science, their ability to observe, question, and their excitement has changed.*

Teachers' conceptual knowledge is critical. Without it, teachers are unable to provide the next learning pathways for students, ask the questions that stimulate the students' thinking, and provide and adjust learning activities to take into account formative assessment data, thus restricting student's learning opportunities and progression in learning. The teachers identified their own knowledge of science as being insufficient to allow them to raise student achievement and became intent on resolving the problem through professional development and discussion. The result of this is evident in the cycles of action research (see Chapter 4).

#### *Teachers' formative assessment practice*

Changes to the teachers' formative assessment practice began with sharing learning goals (learning intentions) with the students, being able to identify 'what to notice' (Harlen, 2000), developing notions of standards, and having appropriate expectations of student achievement. The matrix and exemplars were instrumental in developing teachers' knowledge and understanding of standards, providing the next learning step for students and providing feedback criteria to students about their learning. These are all fundamental principles of formative assessment.

In developing a notion of the next learning steps, teachers came to understand worthwhile learning goals, thus shifting their teaching and assessment foci. The move from seeing specific 'knowledge' as the goal of science to understanding and accepting as valid the longer-term goals of science, such as "*thinking scientifically, reflecting, justifying*" and "*explaining*

*their understanding*" (all of which required the students to have in-depth science conceptual understanding), was gradual and linked to the teachers' notions of progression in learning.

### *Progression in learning*

In gathering evidence about learning, teachers and students not only need to be clear about the intended learning outcomes and how to achieve these, but, as Sadler (1989) states, how these contribute to longer-term goals. The teachers' notions of progression grew as they began to view science teaching as the progression of on-going worthwhile goals developed from unit to unit and across years, from novice to expert (Gipps, 1999; Harlen, 2000). However, while teachers were able to affect progression from unit to unit within their own classrooms and provide learning pathways for students (Sadler, 1989; Harlen, 2000; Black & William, 2002; Clarke et al., 2003; Huinker & Freckmann, 2004), the notion of school-wide progression was a difficult concept. The inability of teachers to make decisions around school-wide progression is linked to their own limited knowledge of science and science pedagogies and the compartmentalized way in which they used the matrix, as previously discussed. Further experience in using the matrix and investigation of progression is required.

### **Sub-themes to emerge**

#### *The action research / professional development model*

This research study employed principles of professional development and action research. The 'professional development' model was crucial to the impact on teaching and learning in science and put into practice the notions held by Cohen and Hill (2000, cited in Ingvarson et al., 2005); Guskey (2000); Annan et al., (2002); Huinker and Freckmann (2004) and Ingvarson et al., (2005) that professional development should focus on what students are to learn, how to deal with the problems the students may have in learning the content matter, and planning learning experiences to achieve the learning goals. Also vital is the opportunity for teachers to identify and

plan their learning needs, the next cycle of improvement (Ingvarson et al., 2005).

The teachers, in identifying critical elements of change, supported the notion held by Guskey (2000) that the professional 'community' takes achievable and incremental steps towards change with feedback and feed forward being provided in order to maintain the confidence of change:

(T4 int C4)	<i>We are learning too and you have to be content for a while just to have a look at one or two aspects (the matrix) or three or four and develop that and then keep building on your knowledge.</i>
-------------	--

Professional development, as previously discussed, is akin to the principles of action research held by Ebbutt (1985, cited in Cohen et al., 2000) and Elliott (1978, cited in Cohen et al., 2000). Participants in action research are engaged in looking at their own practice, determining where they want to be and identifying the interventions that would allow them to meet their goals.

(T1 int C1)	<i>The science gave us a structure and a framework to use and then (participants) realised I know that, I can do that, or I have done this and then you get the sharing...If you don't have a framework, a point of commonality then it is hard to generate that kind of support and discussion and an idea of sharing.</i>
-------------	---

Opportunities were provided for the teachers to examine student work collaboratively, and in relation to the standards thus leading to a greater understanding of what counts as meeting those standards (Ingvarson et al., 2005; Timperly, 2003). In deprivatising the act of teaching (Annan et al., 2003), teachers were able to gain feedback from their colleagues. Action Research also holds the expectation that participants work as a team and share and collaborate on results of their practice (Kemmis & McTaggart, 1992; Greenwood et al., 1999) with an emphasis placed on improving practice.

This PAR study saw many changes to the teachers' practice and therefore the achievement of the students. This was, in part, due to the length of time and the number of hours invested in the research study. As Garet et al., (2001, cited by Ingvarson et al., 2005) state, professional development is likely to be of a higher quality if it is both sustained over time and involves a substantial number of hours. The researcher was able to provide timely and insightful support (Joyce & Showers, 1984; Schon, 1987) to the teachers. Because of the level of support, the teachers in cycles two, three and four selected contexts of learning that were challenging to them in terms of their science knowledge and the pedagogies necessary to ensure their students engaged with and understood the science concepts. The systematic gathering and analysis of data, meeting the goals of teachers, addressing their real and daily concerns (Guskey 2000; Ingvarson et al., 2005) and, the cyclic and iterative nature of the action research were key factors of the development.

Coburn (2003) asserts that two levels of change occur in professional development, surface change and deep change. The teachers in this research study meet Coburn's criteria for deep change: changes were made to the teachers' underlying assumptions of how students learn as they became more knowledgeable of constructivist theories and their implementation, they significantly developed their understanding of science and science pedagogical skills and knowledge, and they raised their expectations for students. The teachers' beliefs of how students' learn inform what happens in the classroom: it affects the interaction between the teacher and the students, the roles of the students and teacher in the classroom, the manner in which they treat each other, and the patterns and quality of the teacher-pupil dialogue. The teacher participants in this research study changed from being the providers of knowledge and activities to being co-learners with their students, intent on causing thinking and therefore change to occur for their students.

All the teacher participants in the research study commented on the relationship of respect, empathy and trust between the members of the

'learning community'. They identified the support of their colleagues, the quality of the professional discussions and reflection, and the expectation that all teachers would be in part responsible for the development of their colleagues (Le Cornu, 2003) as being a 'highlight' of the research study. The notion of a learning community is also fundamental to action research, as is collaborative activity (Kemmis & McTaggart, 1988, cited in Cohen et al., 2000; Elliot, 1991, cited in Cohen et al., 2000).

The PAR model supported the notions of Cohen and Hill (2000, cited in Ingvarson et al., 2005) that professional learning is more likely to improve student learning if it increases teachers' understanding of the content they teach, how students should learn it and how to represent and convey that content in meaningful ways. The PAR design was influenced by the extent to which the teachers were able and prepared to engage in their own development, the 'teachers as learners'.

#### *Teacher as a learner*

The 'teacher as a learner' had considerable impact on the extent to which the teacher participants changed their practice and the way in which they participated in the Action Research study. Guskey (2000) and Ingvarson et al., (2005) suggest that the extent to which professional development influences knowledge and practice is enhanced by the extent to which that programme also strengthens the 'teacher as the learner' and the level of professional community. The matrix and exemplars provided the vision (Shulman & Shulman, 2004) and caused the teachers to confront previously taken for granted assumptions about teaching and learning (Le Cornu, 2003), thereby ensuring that their students' achievement was not compromised by their own lack of knowledge.

Such was the level of community, the teacher participants' dialogue was focused on their students' learning and the teachers accepted responsibility for the achievement of all the students in their team. The teachers became co-learners and co-mentors in a process of discovery where the focus was

not just on their own learning but also on how they could help their 'partners' learning (Le Cornu, 2003). Teachers at both School A and School B identified the importance of working collaboratively and the changes they had made to the way they worked:

(T2 int C4)      *We have been purpose orientated and that has been critical. Next year we are going to set things up to work together, and work around a focus. We will plan and discuss our units during the period. We will try and work in the same way.*

Le Cornu and Peters (2005) assert that students' levels of participation in the learning process are inextricably linked to their teacher's levels of participation in their own learning processes, and this was certainly evident as the cycles of the Action Research progressed in this research study. As the teachers became more reflective and were prepared to take risks, they provided more challenging opportunities for their students, as illustrated in Cycle Three and Four (see Chapter 4).

### **Chapter summary**

The matrix and exemplars were the vehicles for change. The matrix provided a framework for identifying and describing key goals of science. In endeavouring to understand and meet these goals, the assumptions teachers held about teaching and learning in science were challenged. The teacher participants became increasingly concerned with the cognitive engagement and management of students' learning and provided learning opportunities that took into account the learning needs of individuals. Teachers no longer provided pre-determined activities that developed the science 'truths', but rather provided learning opportunities that encouraged debate and discussion, allowed students to become aware of differing views and the gaps in their understandings, enabled students to work collaboratively, and encouraged students to reflect on their learning and change their minds. Teachers scaffolded students' learning and made

changes to pedagogies in order to support their students' learning so that thinking and changes to understandings would occur. This in turn necessitated that teachers improve their science conceptual understandings. In working with the exemplars and matrix, teachers had their own scientific knowledge developed and came to understand expectations and standards of teaching and learning in science and the learning pathways for students. The exemplars provided teaching strategies, contexts of learning and samples of students' work against which teachers could moderate their students' work.

Teachers used the matrix aspects and indicators in a variety of ways. Some aspects and indicators were used for goal setting, determining the structure of the learning opportunities and providing assessment criteria, while others were inherent in the learning activities. Considerable discussion about the aspects and indicators was necessary to ensure that the teachers held a common understanding about their meaning and intent.

The participatory action research/professional development design was critical in effecting the changes to the teachers' practice and the students' achievement. The systematic gathering and analysis of data, meeting the teachers' needs, the iterative nature of the research, the number of hours and the length of time of the development were fundamental to its success. The teacher participants worked collaboratively and supported their colleagues as they reflected on and changed their practice; a way of working that they can transfer to other situations. Each teacher was committed to changing their practice and developing the necessary knowledge and understanding to ensure the achievement of their students in science.

## **CHAPTER 6: Conclusion**

### **Introduction**

This action research study set out to investigate the impact of the Science Exemplars and associated Matrix on science teaching and learning and this chapter draws the research study to a close. Key findings are discussed with specific reference being made to the use and implementation of a National Assessment tool, the Exemplars and associated Matrix. An explanation of why the methodology was chosen and the validity of the research is provided. Consideration of the limitations of the study are acknowledged and recommendations for future research are made.

The findings of this research, while clearly showing evidence of improvement to teaching and learning in science, have raised issues and concerns about the effectiveness of the exemplars and the matrix if they are not thoughtfully implemented. In identifying critical factors this research study can add to the limited literature around the use and implementation of the exemplars and matrix.

### **Factors to consider when using and implementing the National exemplars and matrix**

It is the view of the researcher that the exemplars and matrix need to be introduced to schools in two contexts: firstly that of formative assessment and secondly the curriculum context. Formative assessment involves gathering evidence about students' learning (Harlen, 2000) and requires that both teachers and students are clear about the intended learning outcomes, know how to achieve these and how they contribute to longer term goals (Sadler, 1989; Harlen, 2000; Black & Wiliam, 2002; Clarke, 2001; Clarke et al., 2003; Huinker & Freckmann, 2004). Sadler (1987); Gipps (1999); Harlen (2000) and Black and Wiliam (2002) contend that exemplars and a framework (matrix) provide criteria and denote standards for evaluating any learning achievements.

Understanding the aspects and indicators of the matrix requires knowledge of science and the pedagogies required to affect them. Some aspects and indicators are context dependent, rather than generalised skills and processes (Resnick, 1987 cited in Gipps, 1999); Gipps, 1999), which can cause confusion unless they are interpreted with the benefit of science knowledge. As primary teachers generally have little idea of the nature of science and science conceptual knowledge many of the aspects and indicators may appear as abstract ideas. Therefore the aspects and indicators must be put into action and introduced in the context of teaching and learning in science.

Some aspects and indicators proved to be difficult to understand, some differences between indicators over curriculum levels are minimal, and there appear to be similar aspects across matrices. As a consequence they are open to interpretation. This then raises the issue of comparability, especially so if the intention is for the matrix to be used as a National tool for determining 'evaluative criteria' (Chamberlain, 2000). Therefore it is essential that discussions are initiated and facilitated by people with both curriculum and assessment knowledge. While it could be argued that the purpose of the exemplars is to provide the explanation or model, not all aspects are exemplified.

Teachers tend to view the exemplars as providing the inspiration and model of how to teach science and initially use the exemplars as a 'science unit'. Without support and direction they tend not to compare their students' work with that of the exemplar in order to develop a notion of appropriate standards and expectations or the evaluative criteria (Sadler, 1987; Gipps, 1999; Harlen, 2000; Black & Wiliam, 2002). Again, in order to do this in a meaningful way, curriculum expertise is necessary.

Understanding of formative assessment practice (Sadler, 1989; Black & Wiliam, 1998; Gipps, 1999; Harlen, 2000; Clarke et al., 2003) is also vital to the implementation of the matrix and exemplars. This study has shown that even with a fundamental understanding of formative assessment, teachers

find it difficult to use the matrix and exemplars for assessment purposes. After considerable professional development, the teacher participants still viewed the matrix as defining teaching rather than learning.

(T4 int C3) *The matrix is more about guiding teaching, rather than assessing students. Eventually it will become more useful for assessment practices, at the moment it is most useful for my teaching.*

Issues around assessment, especially that of progression, emerged and signalled the differing views teachers held. To moderate these views, considerable discussion and professional development about formative assessment was required.

Some teachers viewed progression as occurring only within an aspect, while others were concerned with how they could 'cover' all of the aspects within a curriculum level over a two-year period. The notion of using aspects and indicators as assessment criteria to be used formatively from one unit to the next was challenging for teachers and the idea of school-wide progression of aspects is still unresolved. It is conceivable that the purpose of the National Exemplars and Matrix as an assessment tool might not be realised unless significant support is provided.

The way in which the exemplars and matrix are introduced to teachers, and the way in which they are then used, impacts on the teachers' understanding and the issues that may arise. The teachers in this study initially selected two aspects to develop, as they were overwhelmed with the enormity of the matrix. They then added aspects as they became familiar with the matrix and the initial aspects became tacit knowledge.

However in atomising the matrix in this way, issues of progression were compounded as teachers only progressed students across a narrow aspect. It became clear that there was a need to frequently visit the more global "overall progression" so that teachers were constantly reminded of the whole

and not just the parts. The teachers considered the “overall progression” to be too broad to use for assessment purposes, as they did not have sufficient knowledge to be able to understand or identify what the criteria for progression were. As such, they tended to ignore it, therefore compounding the focus on and atomising of individual aspects.

In ensuring that teachers come to understand the aspects and indicators, it is critical that teachers include them as learning goals, firstly in their planning and then as learning goals shared and reflected on with their students. Referring to the matrix regularly during the teaching of the unit and asking teachers to describe their students and share student work in relation to the matrix, proved to be advantageous in developing teachers’ understanding. The teachers also needed support in developing appropriate pedagogies for the teaching of science and in developing their own science knowledge to manage the pedagogies. Some in-depth knowledge is required in order to effect this process.

The participatory action research model is an effective way of providing professional development, as the teachers are participants and opportunities are created for them to participate so that real concerns, which are particular to them, are addressed as they reflect on and change their practice. Developing a collective understanding through the creation of knowledge enhances the group’s effectiveness as it functions at a metacognitive rather than a functional level and therefore serves to develop a sense of community (Head, 2003).

All of these factors, plus the teachers themselves, who demonstrated ‘the teacher as a learner’, accounted for the success of the project in improving teaching and learning in science. The teachers would consider that their understanding of the matrix and the exemplars is still under development. Over the timeframe of the project, they worked with three of the four matrices and felt competent in the use of one of the matrices. This then is an indication of the time, the support and the type of development model

needed to bring about effective implementation of the National Matrix and Exemplars.

### **Methodology selected**

Participatory action research was chosen because of its alignment to professional development and was therefore acceptable to the teachers participating in the research. PAR provides understanding and description of peoples' personal experiences and is responsive to local situations and conditions, and the needs of the stakeholders. Data are therefore collected in a naturalistic setting. Democracy in knowledge production gives the participants a stake in the quality of the results and increases the reliability of the information, as does the combined methods of triangulation, both group and individual. Action research is also responsive to the changes that occur during the study.

### **Triangulation**

Seven teachers, 150 students and two schools participated in the participatory action research. The relative size of the study also allowed the researcher to provide more support and time to the participants. The variety of data collection methods allowed triangulation of the research evidence, so that the researcher could have confidence that the emerged themes were valid. The two participating schools, while coming from the same region, were cross-sectional in that they were drawn from different decile ratings.

A number of visits took place over a four-term period (one school year). Because of the time scale, the action research was iterative and as Altrichter (1993) asserts, it is the iterative nature of action research that is its main rigour. The researcher conducted forty-five classroom observations of up to one hour, twenty-one interviews of an hour, forty-five interventions, and seven professional development and planning phases. The interviews and observations provided rich and detailed data (Sieber, 1973, cited in Johnson & Onwuegbuzie, 2004) that allowed analysis of key themes.

### **Limitations of the research**

Given the complexity of teaching and learning in science and the limitations of the research study there is much this thesis does not encompass. The limitations of the research are that it was confined to two schools, both in the same region and both primary schools, and that only the junior syndicates of each of the schools were involved in the research. While seven teachers and 150, five to nine year old students were involved; the research did not extend to older students.

### **Contribution to the literature**

As stated by Fitz-Gibbon (1997, cited in Cohen et al., 2000) the educational community needs evidence on which to base its judgements and actions, and the implementation of untried and untested recommendations in educational practice borders on being unethical. This PAR study has attempted in a small way to bridge the gap between theory and practice by investigating the National Exemplars and associated Matrix as an assessment tool and its impact on teaching and learning.

The research study supports the literature of pedagogical content knowledge, theory based reforms in which teachers' understanding and depth of content knowledge is critical, formative assessment theory and practice, the effectiveness of the exemplars and matrix as an assessment tool, effective professional development and participatory action research. This study could also build on and add to the literature and the research of Poskitt (2002) on the implementation of the New Zealand National Exemplars and associated Matrix as an assessment tool for teaching and learning. Poskitt's research followed the early implementation of the exemplars and matrix and focused on the effect of the exemplars and matrix on teaching and learning within curriculum areas, but did not look at individual teacher development within a curriculum area, over time, as does this study.

Conclusions drawn from this study could be generalisable to other similarly talented teachers. The teacher participants were effective classroom practitioners where a culture of learning existed, they knew their students, were aware of the problems that might emerge and knew how to deal with these. Each of the two syndicates worked in a collaborative way, which was enhanced through the PAR study.

As an adviser in Science Education and in Assessment, the findings have informed my practice by making me cognisant of issues that could arise in using the matrix and exemplars and their impact of the teaching and learning in science. My 'traditional' views of professional development have been challenged by the action research design: its iterative nature, the length of time committed to the development, the number and frequency of the observations, and the feedback and opportunities for reflection. A culture of learning is vital to the success of an action research study. The 'teacher as a learner' and the degree of 'learning community' are more meaningfully established and therefore effective in changing teacher practice if the participants have ownership of the 'problems' under investigation.

While this approach was efficient with a small group of teachers, the sustainability and effectiveness over a large school as a whole school development would require further investigation. However, as Guskey (2002) states, there is not one method of professional development and rather it needs to be suited to the context or situation.

### **Recommendations for further research**

This Action Research study has identified further areas of research. Some issues to arise during this study have been unresolved because of the limitations of the study. Progression in Science Education, at a classroom level and a school-wide level is such an issue. Teachers' limited science conceptual knowledge and understanding of the nature of science made the interpretation and understanding of the matrix difficult. However these difficulties with the matrix may reflect not only teachers' limited scientific

understandings but also some potential areas of refinement for the matrix, an aspect that would require more extensive research to ascertain.

The difficulties in interpretation also raise issues about the reliability and comparability of the matrix as a national assessment tool. Will all teachers and all schools interpret the aspects and indicators in the same way? Does this indeed matter? Further research around the matrix and exemplars to include a larger population, more diverse teachers, a wider age range of students and different types of schools, and in another curriculum area could allow different themes to emerge which may be convergent with or divergent from the findings of this research study.

### **Chapter summary**

The research study has shown the potential impact of the exemplars and matrix and, has successfully put into practice the theory, bridging the gap between theory and practice, the academic and the practitioner. The matrix, with its underpinning of constructivist principles, challenged the teacher participants to see their teaching as a process that focuses on conceptual change (von Glaserfeld, 1990; Watts, 1994). Having been made aware of the 'worthwhile goals of science', teachers had the will (Shulman & Shulman, 2004) and were able to put into practice, with support, some of these goals and in so doing changed their own practice and the learning outcomes for their students.

Critical to the development, the changes to teachers' practice and the outcomes for students, was the professional development and PAR design. The teachers identified as being vital the sense of community and the collaborative way of working, which was enhanced by and in turn enhanced the 'teacher as a learner'.

The teachers' commitment to their students' learning, and the impact on teaching and learning, assessment and the resultant teacher–student interactions in science learning are clearly evident in the following comment:

(T4 int C3)

*It is lovely and people are getting their materials (science) together and just having quite interesting discussions with children and you know the parents are coming in and talking about the science. It is a whole culture of learning.*

## References

- Alton-Lee, A. (2001). Research ethics, classroom research and educational practice. In M. Tolich (Ed.), *Research ethics in Aotearoa New Zealand*. Auckland: Pearson Education.
- Alton-Lee, A. (2002). *Quality teaching for diverse students: Best evidence synthesis*. Wellington: Ministry of Education.
- Altrichter, H. (1993). The concept of quality in action research: Giving practitioners a voice in educational research. In M. Schratz (Ed.), *Qualitative voices in educational research*. London: Falmer.
- Annan, B., Lai, M. K., & Robinson, V. (2003). Teacher talk to improve teaching practices. *Set 1 2003*. New Zealand Council of Educational Research.
- Askew, S. (Ed.), (2000). *Feedback for learning*. (Ed.). London: Routledge Falmer.
- Asoko, H. (2002). Developing conceptual understanding in primary science. *Cambridge Journal of Education*, 32(2), 153-164. University of Cambridge Faculty of Education.
- Barth, R. (1990). *Improving schools from within*. San Francisco: Jossey Bass.
- Bell, B., & Baker, R. (Eds.), (1997). *Developing the science curriculum in Aotearoa New Zealand*. New Zealand: Longman.
- Black, P. & William, D. (1998). *Inside the black box: Raising standards through classroom assessment*. London: King's College, University of London.

- Black, P., & Wiliam, D. (1999). *Assessment for learning: Beyond the black box*. London: King's College, University of London.
- Black, P., & Wiliam, D. (2002). *Working inside the black box: Assessment for learning in the classroom*. London: King's College, University of London.
- Carr, M., Barker, M., Bell, B., Biddulph, F., Jones, A., Pearson, J., & Symington, D. (1994). The constructivist paradigm and some implications for science content and pedagogy. In P. Fenshaw, R. Gunstone, & R. White (Eds.). *The content of science. A constructivist approach to its teaching and learning*. London: Falmer Press.
- Chamberlain, M. (2000). *Draft science national exemplars and matrix*. Wellington: Ministry of Education.
- Clarke, S. (2001). *Unlocking formative assessment: Practical strategies for enhancing students' learning in the primary classroom*. London: Hodder & Stoughton.
- Clarke, S., Timperly, H., & Hattie, J. (2003). *Unlocking formative assessment: Practical strategies for enhancing students' learning in the primary and intermediate classroom* (New Zealand 1st ed.). Auckland: Hodder Moa Beckett.
- Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, 32(6), 3-12.
- Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.). London: Routledge.

- Coleman, M., & Lumby, J. (1999). The significance of site-based practitioner research in educational management. In D. Middlewood, M. Coleman & J. Lumby (Eds.), *Practitioner research in education making a difference*. London: Sage Publications.
- Costello, P.J.M. (2003). *Action research*. London: Continuum.
- Crooks, T. J. (1988). The impact of classroom evaluation practices on students. *Review of Educational Research*, 58 (4), 438-481.
- Dawson, V. M., & Taylor, P. (1998). Establishing open and critical discourses in the science classroom: Reflecting on initial difficulties. *Research in Science Education*, 28(3), 317-336.
- Davies, A. (2000). *Making classroom assessment work*. Canada: Connection Publishing.
- Dufour, R. (2004). What is a professional learning community? *Educational Leadership*, 61(8), 6-11.
- Fiszer, E. P. (2004). *How teachers learn best: An ongoing professional development model*. Maryland: Scarecrow Education.
- Gipps, C. (1999). *Beyond testing: Towards a theory of educational assessment*, London: Routledge.
- Glesne, C. (1999). Being there: Developing understanding through participant observations. *Becoming qualitative researchers: An introduction* (2nd ed.) New York. Longman.
- Greenwood, D., Whyte, W., & Harkavy, I. (1993). Participatory action research as a process and as a goal. *Human Relations*, 46(2), 175-192.

- Guskey, T.R. (2000). Does it make a difference? Evaluating professional development. *Educational Leadership*, 59(6), 45-51.
- Hackling, M., & Fairbrother, R. (1996). Helping students to do open investigations in science. *Australian Science Teachers Journal* 4(4), 26-33. Accessed April 2006 from <http://www.adelaide.edu.au>.
- Harlen, W. (2000). *The teaching of science in primary science* (3rd ed.). London: David Fulton Publishers.
- Hattie, J. A. (2002). *What are the attributes of excellent teachers?* Paper presented at the New Zealand Council for Educational Research Conference, Wellington.
- Head, G. (2003). Effective collaboration: deep collaboration as an essential element of the learning process. *Journal of Educational Enquiry*, 4(2), 47-65.
- Hennessy, S. (1993). Situated cognition and cognitive apprenticeship: Implications for classroom learning. *Studies in Science Education*, 22, 1-41.
- Hubbard, R. S., & Power, B. M. (1999). Living the questions: A guide for teacher-researchers. Accessed April 2006 from <http://www.educ.msu.edu/>.
- Huinker, D., & Freckmann, J. (2004). Supporting teacher learning. *Teaching children mathematics*. March 2004. 352-357.
- Ingvarson, I., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programmes on teachers' knowledge, practice, student outcomes and efficacy. *Education Policy Analysis Archives*. 13(10), 1-26.

- Johnson, B. R., & Onwuegbuzie, A.J., (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14-26.
- Joyce, B. R., & Showers, J. (1982). The coaching of teaching. *Educational Leadership*, 40(1), 4-10.
- Keating, J., Diaz-Greenberg, R., Baldwin, M. & Thousand, J. (1998). A collaborative action research model for teacher preparation programs. *Journal of Teacher Education*, 49(5), 381-390.
- Kemmis, S., & McTaggart, R. (1992). *The Action Research Planner* (3rd ed.). Victoria: Deakin University Press.
- Kemmis, S., & Wilkinson, M. (1998). Participatory action research and the study of practice. In B. Atweh, S. Kemmis & P. Weeks (Eds.), *Action research in practice*. London: Routledge.
- Lawson, A. E., & Weser, J. (1990). The rejection of nonscientific belief about life: Effects of instruction and reasoning skills. *Journal of Research in Science Teaching*, 27(6), 589-606.
- Le Cornu, R. (2003). *Peer mentoring: The way forward for developing teachers as leaders*. Paper presented at the Australian Teacher Education Association, Melbourne. Accessed April 2006 from [Rosie.lecornu@unisa.edu.au](mailto:Rosie.lecornu@unisa.edu.au).
- Le Cornu, R., & Peters, J. (2005). Towards constructivist classrooms: The role of the reflective teacher. *Journal of Educational Enquiry*, 6(1), 50-64.
- Massey University Human Ethics Committee. (2002). Code of ethical conduct for research, teaching and evaluating involving human participants. (Revised 30 October 2002). Accessed July 2003 from <http://www.massey.ac.nz/muhec/downloads.html>.

- Masters, G., & Forster, M. (1996). *Developmental assessment: ACER assessment resource kit*. Victoria: Council of Educational Research.
- Ministry of Education. (2002). *Curriculum update issue: February*. Wellington: Ministry of Education.
- Murphy, P., & McCormick, R. (1997). Students constructing conceptual knowledge through investigating. *Research in Science Education*, (Eds.). 27(3), 461-481.
- Novak, J.D., Mintzes, J., & Wandersee, J. (2000). *Assessing student understanding*. New York: Academic Press.
- Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.
- Pellegrino, J., Chudowsky, N., & Glaser, R. (Eds.). (2001). *Knowing what students know. The science and design of educational assessment*. Washington DC: National Academy Press.
- Poskitt, J. (2002). National consultation on exemplars. What difference does it make for teachers? *Set 3, 2002*. Wellington: New Zealand Council for Educational Research.
- Ritchie, S. (1998). The teacher's role in the transformation of students' understanding. *Research in Science Education*, 28(2), 169-185.
- Sadler, R. (1987). Specifying and promulgating achievement standards. *Oxford Review of Education*, 13(2), 191-209.

- Sadler, R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 19-144.
- Sadler, R. (1998). Formative Assessment: revisiting the territory. *Assessment in Education* 5(1), 77-84.
- Schon, D. (1987). *The reflective practitioner*. New York: Basic Books.
- Scott, D., & Usher, R. (1999). *Researching education. Data, methods and theory in educational enquiry*. London: Continuum.
- Segall, A. (2004). Revisiting pedagogical content knowledge: The pedagogy of content/the content of pedagogy. *Teaching and Teacher Education*, 20, 489-504.
- Shepardson, D. P. (1997). Of butterflies and beetles: Ways of seeing and talking about insect life cycles. *Journal of Research in Science Teaching*, 34, 873-889.
- Shulman, L. S., & Shulman, J.H. (2004). How and what teachers learn: A shifting perspective. *Journal of Curriculum Studies*, 36(2), 257-271.
- Solomon, J. (1994). The rise and fall of constructivism. *Studies in Science Education*, 23, 1-19.
- Sprod, T. (1998). I can change your opinion on that: Social constructivist whole class discussions and their effect on scientific reasoning. *Research in Science Education*, 28(4), 463-480.
- Stahly, L., Krockover, G. and Shepardson, D. (1999). The third grade students' ideas about lunar phases. *Journal of Research in Science Teaching*, 36(2), 159-177.

- Timperley, H. (2003). School improvement and teachers' expectation of achievement. *New Zealand Journal of Educational Studies*, 38(1), 73-88.
- Treagust, D., Duit, R., & Fraser, B. J. (1996). In D. Treagust., R. Duit, & B. J. Fraser (Eds.). *Improving teaching and learning in science and mathematics*. New York: Teachers College Press.
- von Glaserfeld, E. (1990). An exposition on constructivism: Why some like it radical. In R. Davis, C. Maher., & N. Noddings (Eds.). *Constructivist views on the teaching and learning of mathematics. Journal of Research in Mathematics Education Monograph 4*, 19-29. Reston, VA: National Council of Teachers of Mathematics.
- Watts, M. (1994). Constructivism, re-constructivism and task-orientated problem-solving. In P. Fenshaw, R. Gunstone, & R. White (Eds.). *The content of science: A constructivist approach to its teaching and learning*. London: Falmer Press.
- Wiggins, G., & McTighe, J. (1999). *Understanding by design*. Virginia USA: Association For Supervision and Curriculum Development.

# Appendices

Appendix 1 - Exemplars and matrix

- 1(a) Matrices A-D
- 1(b) Exemplar Example
- 1 (c) Terms Used

Appendix 2 - Examples of field notes

- 2(a) Observation Notes
- 2 (b) Notes from discussions at Intervention

Appendix 3 - Core questions asked in the interviews

Appendix 4 - Examples of transcript analysis

Appendix 5 - Information letters and consent forms

- 5(a) Example of letter to Board of Trustees, Principals, Teachers
- 5(b) Example of Consent Form

Appendix 6 - Collation of data from individual interviews

Tables 1-16

Appendix 7 - Planning format sample

# The Science Matrices Progress Indicators

THE NEW ZEALAND CURRICULUM EXEMPLARS



ACCESS THE SCIENCE MATRIX PAGES ONLINE AT [www.tki.org.nz/r/assessment/exemplars/sci/index\\_e.php](http://www.tki.org.nz/r/assessment/exemplars/sci/index_e.php)

## DEVELOPING INTEREST AND RELATING SCIENTIFIC LEARNING TO THE WIDER WORLD: ABOUT THIS MATRIX

This matrix focuses on interest, attitudes, and values in science. The progress indicators relate to the general aims of science education (*Science in the New Zealand Curriculum*, page 9), which provide a foundation for effective, lifelong science learning and an understanding of the role that science plays in societies.

## SCIENCE MATRIX A: DEVELOPING INTEREST AND RELATING SCIENTIFIC LEARNING TO THE WIDER WORLD

### KEY ASPECT OF LEARNING: EXPERIENCING AND SHOWING AWE, WONDER, AND INTEREST

At all levels, science education fosters students' ability to:

- display curiosity about the world around them;
- demonstrate enthusiasm and excitement about how science works;
- take an interest in a particular scientific topic or activity;
- pursue scientific interests, without prompting, outside the formal learning environment;
- display initiative and commitment when seeking answers to their questions;
- express awe and wonder or enthusiasm about an observation, experience, idea, or explanation;
- develop and declare an interest in some aspect of science or the environment;
- persevere to solve problems and overcome difficulties while pursuing their own interest in science;
- share with and involve others in their own interest in science;
- take responsibility for their own and others' learning in science and the environment.

KEY ASPECTS OF LEARNING	PROGRESS INDICATORS				
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
Caring for the Environment	Demonstrates care for living things and their surroundings.	Takes an active role in the care of living things and their surroundings in and beyond the classroom.	Discusses how humans use living things and the environment. Takes collaborative action to protect and enhance their local environment.	Debates the effects of human activity on the living and physical world. Justifies their views. Takes effective, collaborative action to protect and enhance their local environment.	Develops arguments for appropriate human actions and the uses of science in the environment. Justifies positions by prioritising values and taking effective collaborative action for the wider environment.
Engaging in Social Issues	Shares ideas about simple, local social issues related to science and the environment.	Discusses simple social issues related to science and the environment, supporting their views.	Uses their own understanding to discuss and justify their views on social issues related to science and the environment.	Seeks and uses scientific information to debate social issues related to science and the environment. Makes a case for effective action.	Seeks and uses scientific understanding and evidence to debate more complex social issues related to science and the environment. Supports collaborative action and/or tries to convince others to do so.



## INVESTIGATING IN SCIENCE: ABOUT THIS MATRIX

This matrix should be selected if the teacher's intention for learning is to develop students' abilities to carry out scientific investigations to answer their own and others' questions. The matrix links to the integrating strand Developing Scientific Skills and Attitudes (*Science in the New Zealand Curriculum*, pages 42–51) and reflects some of the processes and conventions of the scientific community.

### About Investigating

These indicators are intended to apply to a broad range of types of investigation. While carrying out scientific investigations, students need to be able to select and use the key aspects of learning most appropriate to the context of their scientific work. The order of the key aspects of learning in this matrix may appear to form a logical sequence, but it is unlikely to reflect the actual creative experience of an investigation. Evaluation, processing, interpreting, and communication are ongoing aspects of any investigation and can lead to changes as the investigation proceeds. (See *Science in the New Zealand Curriculum*, page 47, note 3.)

The types of investigations include fair testing, pattern seeking, classifying and identifying, making things or developing systems, researching, and exploring.

### Scientific Conventions (referred to in the progress indicators)

- Work safely (e.g., ensure that hazards are identified and appropriate measures taken).
- Behave ethically (e.g., cause no unnecessary suffering to living things).
- Report results and procedures clearly and honestly (e.g., use diagrams, tables, graphs; separate questions, procedures, and outcomes).
- Try to ensure that the evidence presented is credible (e.g., make precise observations, use instruments to measure as accurately as necessary, repeat measurements to check uncertainty).
- Try to eliminate competing explanations (e.g., control the variables).
- Work collaboratively.
- Take into account previous research.

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
OVERALL PROGRESSION	Participates in investigative activities.	Contributes meaningful ideas and actively participates in an investigation.	Initiates aspects of systematic investigations within a supportive framework.	With support, initiates and sustains investigations using some scientific conventions.	Initiates and persists with systematic and meaningful investigations using scientific conventions.

## SCIENCE MATRIX B: INVESTIGATING IN SCIENCE

KEY ASPECTS OF LEARNING	PROGRESS INDICATORS				
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
<b>Exploring a Situation</b>	Contributes observations to a class exploration. With support, identifies observed similarities and differences.	Makes observations and looks for patterns or relationships, with prompting as needed. Describes some observations.	Makes a series of observations to look for patterns or relationships. Describes or represents the observations made with some accuracy and detail.	Makes more detailed observations and suggests patterns and/or relationships related to a scientific idea. Communicates about observations with accuracy and detail.	Makes increasingly focused and detailed observations relevant to identified scientific patterns and relationships. Communicates detailed observations accurately and systematically.
<b>Asking Questions</b>	With support, asks questions about a given situation.	Contributes questions in discussions.	Generates questions and participates in choosing questions to investigate.	Generates, discusses, and chooses interesting questions to investigate.	Refines worthwhile questions for systematic investigation.
<b>Making Predictions</b>	Says what they think will happen in simple investigative situations.	Predicts possible outcomes for simple trials and gives reasons.	Uses their own ideas to make testable predictions.	Uses their developing scientific ideas to make testable predictions.	Uses scientific ideas to make testable predictions.
<b>Using Systematic Approaches and Scientific Conventions</b>	Collects and records simple data from observations.	Carries out observations and simple trials based on their own ideas and collects relevant data.	Plans and carries out more systematic trials, using measurement to identify patterns and test ideas. Suggests more than one way to investigate a question. Begins to use some scientific conventions.	Plans and carries out systematic investigations to gather evidence to test their ideas. Uses an increasing range of measurements and conventions.	Plans and carries out systematic investigations to produce evidence supporting a scientific idea or answering a science-related question. Uses appropriate data-gathering instruments and conventions.
<b>Processing and Interpreting</b>	With prompting, identifies observed similarities and differences to reach conclusions in simple investigations.	Reaches conclusions to simple investigations that are linked to their own understanding.	Organises data to display obvious trends and patterns and to reach conclusions. Reaches simple conclusions and links them to their own understandings.	Organises data to display trends, patterns, and relationships. Uses findings to draw conclusions related to simple scientific ideas.	Selects ways to organise data to identify trends and relationships. Reaches relevant conclusions, recognising how these relate to scientific ideas.
<b>Evaluating the Investigative Process as a Continuous Activity</b>	Participates in teacher-assisted evaluations.	Talks about features of investigations and suggests simple improvements.	With support, looks for strengths and weaknesses in their own investigations and suggests improvements.	Identifies the strengths and weaknesses of their own and others' investigations and makes appropriate improvements. Reviews data-gathering procedures honestly.	Identifies and reflects on the strengths and weaknesses of their own and others' investigations to inform the next step. With support, critiques data-gathering procedures in order to recognise limitations to the claims that can be made from the data.
<b>Reporting</b>	Talks freely about ideas and aspects of their investigation.	Reports on some or all of their investigation in an organised way. Refers to their observations.	Presents an organised report linking findings to their observations.	Presents a well-organised report using data to support their conclusions.	Presents a selective and well-reasoned report supported by relevant data.

## THINKING IN SCIENTIFIC WAYS: ABOUT THIS MATRIX

This matrix should be selected if the teacher's intention for learning is to develop students' abilities to construct their own understanding in scientific discussions with others. The focus is on exploring science as a human activity, understanding the thinking and working processes in communities of scientists, and modelling some of these processes in school science. The progress indicators link to the integrating strand Making Sense of the Nature of Science and Its Relationship to Technology (*Science in the New Zealand Curriculum*, pages 24–41) and reflect the values and procedures of the scientific community as well as learning strategies known to develop personal understanding. Teachers can apply them to students' own school-based science or use them to help students explore the stories of professional science in the past or present.

Explanations often involve the use of analogies, metaphors, and models.

OVERALL PROGRESSION	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
	Contributes to a discussion that seeks to explain an experience.	Offers relevant contributions to a scientific discussion.	Considers and justifies contributions to a scientific discussion.	Considers alternatives and uses evidence to justify preferred theories and explanations.	Debates alternatives and uses evidence to support or challenge theories and explanations.

## SCIENCE MATRIX C: THINKING IN SCIENTIFIC WAYS

KEY ASPECTS OF LEARNING	PROGRESS INDICATORS				
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
<b>Suggesting Explanations</b>	Offers simple explanations for observations or events.	Suggests cause-effect links for observations or events.	Suggests explanations supported by some evidence.	Suggests an explanation and considers others linked to the evidence.	With reference to relevant scientific ideas, seeks other possible explanations that fit the evidence.
<b>Comparing and Evaluating Explanations</b>	Begins to use their own experiences to support their ideas. Recognises that other people may have different ideas.	Prefers one explanation. Accepts that their ideas may change if someone suggests a better idea.	Explains why they changed or did not change their ideas, referring to the evidence. With support, clarifies or changes their ideas in the light of the evidence.	Attempts to eliminate or support explanations using evidence. Clarifies or changes their ideas after considering the evidence and argument.	Clarifies or changes their explanation, presenting a case based on evidence and argument. Considers suggested explanations and uses evidence to support or eliminate them.
<b>Evaluating the Quality of Evidence and Accepting Uncertainty</b>	Recognises that 'we' do not have an explanation.	Recognises that 'we' are uncertain about an explanation.	Accepts there is not enough evidence to choose an explanation.	Is aware of the need to assess the quality of evidence.	Assesses the quality of the available evidence.
<b>Understanding How the Science Community Operates</b>	Recognises that scientists find things out and share their ideas.	Recognises that scientists test their ideas to select the best explanations.	Recognises that scientists develop new ideas, building on previous science ideas. Explains that scientists seek out evidence to support or refute ideas.	Recognises that scientists debate their ideas with others in the scientific community. Explains that acceptance of an idea depends on evidence and argument.	Recognises that scientists strive to add to or change the understandings held by the scientific community. Explains that scientists present their ideas for critical scrutiny by other scientists.

# Progress Indicators

ACCESS THE SCIENCE MATRIX PAGES ONLINE AT [www.tki.org.nz/r/assessment/exemplars/sci/index\\_e.php](http://www.tki.org.nz/r/assessment/exemplars/sci/index_e.php)

## DEVELOPING AND COMMUNICATING SCIENTIFIC UNDERSTANDING: ABOUT THIS MATRIX

This matrix should be selected if the teacher's intention for learning is to develop students' abilities to explain events using accepted scientific ideas. The focus is on using scientific ideas to explain events and phenomena. The progress indicators relate to the four contextual strands: Making Sense of the Living World, Making Sense of the Material World, Making Sense of the Physical World, and Making Sense of Planet Earth and Beyond.

Specific learning contexts are not identified in either the matrix or the curriculum because, in practice, teachers will choose the contexts that are most appropriate for their students. Teachers can refer to resources such as the Ministry of Education's Making Better Sense series and Building Science Concepts series for specific content knowledge.

OVERALL PROGRESSION	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
	Shares their explanations about experiences and observations.	Begins to use some scientific ideas to explain everyday events or experiences.	Uses scientific ideas to explain some everyday events or experiences.	Links scientific ideas to explain everyday events or experiences.	Uses scientific ideas coherently to explain everyday and unfamiliar events or experiences.

## SCIENCE MATRIX D: DEVELOPING AND COMMUNICATING SCIENTIFIC UNDERSTANDING

KEY ASPECTS OF LEARNING	PROGRESS INDICATORS				
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
<b>Using Scientific Ideas in Constructing Explanations</b>	Shares ideas about scientific experiences.	Offers explanations for experiences, using some scientific ideas.	Constructs a plausible explanation for an experience, using some scientific ideas.	Constructs an explanation for an experience, using appropriate scientific ideas.	Constructs a well-reasoned and coherent explanation for an experience, using significant and appropriate scientific ideas.
<b>Using Scientific Vocabulary</b>	Explores new vocabulary and uses it to label observable features.	Experiments with vocabulary and uses correct labels to describe experiences.	Develops and uses scientific vocabulary and symbols. Recognises that some words have special scientific meanings.	Uses a range of scientific terms and symbols appropriately. Correctly distinguishes between scientific and everyday meanings for terms used.	Uses a range of scientific terms and symbols appropriately, with increasing reference to abstract ideas.
<b>Communicates Explanations Using Aids</b>	Talks about their ideas.	Begins to explain with the help of simple aids.	Communicates scientific ideas with the help of aids.	Helps an audience to understand a scientific explanation with the help of aids.	Helps an audience to understand scientific ideas and explanations, using aids appropriately.
<b>Using Quantitative Ideas</b>	Makes comparative statements.	Makes comparative statements about relationships.	Recognises that we use measurement to increase precision in explanations.	Uses measurement and reference to quantities in explanations.	Begins to use quantitative relationships as part of explanations.
<b>Reflecting on Their Understanding</b>	Is aware of changes in their own understanding.	Describes changes in their own understanding.	Discusses the changes in their own scientific ideas.	With support, evaluates their own explanations and scientific understanding.	Evaluates their own explanations and scientific understanding and the connections they have made.

# 1(b) Exemplar Example



LEVEL 1 2 3 4 5

## Leaves Sort-up

### THE LEARNING CONTEXT

The teacher's intended outcomes were for the students to:

- classify leaves according to observable features
- use observable features of leaves to create keys to group the leaves and name the groups.

The intended outcomes were aligned to the following "big ideas":

- Scientists classify things according to shared features.
- Scientists use labels to distinguish different groups.

The class went for a walk in the school grounds and gathered leaves. The teacher asked the students to group their leaves, using any classification system they chose. The students found it difficult to choose groups for the leaves, so the teacher set them an activity that gave them practice in classifying objects using everyday items. When they were ready, the teacher gave each student a set of the same leaves. She asked them to observe the leaves closely and suggest ways to describe them. This helped the class to discuss and agree on a common language to label the leaves.

During this process, the teacher introduced new vocabulary, such as "serrated". She then asked the students to divide their leaves into two groups and suggest a label for each group. The class repeated this process twice more until they each had eight subgroups.

The teacher encouraged the students to make more detailed observations at each step and, as the investigation progressed, she decided whether to proceed with the next grouping. She determined the students' prior understanding and used this to inform the teaching. She also introduced the structure of a simple key, a commonly used scientific convention, and modelled the sequential process of creating the key for this investigation.

### Teacher-student conversation

Discussing Sam's findings:

- Teacher: Tell me about the leaves you've collected.  
Sam: They're green, mostly, but lots of different greens. These are big ones. This one's really little.  
Teacher: What do they feel like?  
Sam: Some are smooth, but some of them are serrated.  
Teacher: What do you mean by the word "serrated"?  
Sam: They have little prickles on them, like a saw.  
Teacher: Were you surprised by any of your findings?  
Sam: I thought there would be more smooth leaves, but there were nearly as many serrated ones.

### WHERE TO NEXT?

To move Sam towards the next learning step, the teacher could help him to focus on:

- exploring the idea that changing the criteria for classification can result in different groupings using prompts such as "How could you divide the groups again?" and "If we started sorting again, could we sort the leaves in a different way?" (investigating in science)
- observing the features of the leaves more closely, for example, by carefully drawing one of the leaves and labelling the relevant features (developing and communicating scientific understanding).

The teacher could:

- allow Sam to ask his own questions for the next investigation
- return to the idea of observing and classifying items according to their attributes (for example, the physical properties of items in the Material World strand).



LEVEL 1 2 3 4 5

## Leaves Sort-up

### CURRICULUM LINKS

*Science in the New Zealand Curriculum*  
Achievement Objectives

**Level 1: Making Sense of the Nature of Science and Its Relationship to Technology**

Students can share and compare their emerging science ideas.  
*Science in the New Zealand Curriculum*, page 26  
[http://www.tki.org.nz/r/science/curriculum/p26\\_27\\_e.php](http://www.tki.org.nz/r/science/curriculum/p26_27_e.php)

**Levels 1 and 2: Developing Scientific Skills and Attitudes**  
Information gathering: Students can:

- make observations and simple measurements
- talk about their observations and measurements.

*Science in the New Zealand Curriculum*, page 45  
[http://www.tki.org.nz/r/science/curriculum/p44\\_51\\_e.php](http://www.tki.org.nz/r/science/curriculum/p44_51_e.php)

**Level 1: Making Sense of the Living World**

Students can share their experiences relating to the living world, and group the living world according to some of its attributes.  
*Science in the New Zealand Curriculum*, page 54  
[http://www.tki.org.nz/r/science/curriculum/p44\\_51\\_e.php](http://www.tki.org.nz/r/science/curriculum/p44_51_e.php)

*Te Whāriki*

**Strand 5: Exploration**

**Goal 3**

Children experience an environment where they learn strategies for active exploration, thinking and reasoning.

*Te Whāriki: He Whāriki Mātauranga mō ngā Mokopuna o Aotearoa/Early Childhood Curriculum*, page 88

**Goal 4**

Children experience an environment where they develop working theories for making sense of the natural, social, physical, and material worlds.

*Te Whāriki: He Whāriki Mātauranga mō ngā Mokopuna o Aotearoa/Early Childhood Curriculum*, page 90

### REFERENCES

Ministry of Education (1993). *Science in the New Zealand Curriculum*. Wellington: Learning Media.

Ministry of Education (1996). *Te Whāriki: He Whāriki Mātauranga mō ngā Mokopuna o Aotearoa/Early Childhood Curriculum*. Wellington: Learning Media.



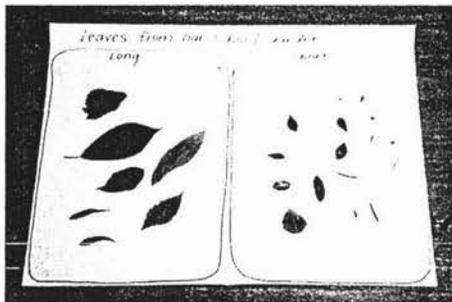
LEVEL 1 2 3 4 5

## Leaves Sort-up

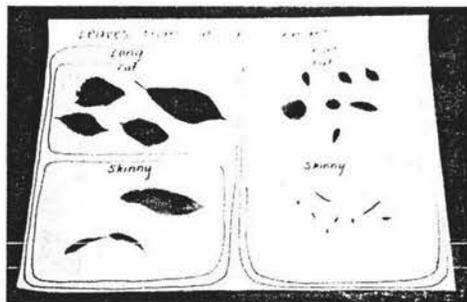
### WHAT THE WORK SHOWS

The class used a classifying and identifying type of investigation to arrange the leaves into groups according to clear criteria.

Sam used his observational evidence to support the various subgroups that he made. He was able to identify two features each time he created two new subgroups.



Two subgroups of leaves



Four subgroups of leaves

### Progress Indicator Investigating in Science

#### Exploring a situation

With support, Sam is able to identify observed similarities and differences in order to create new subgroups.

#### Using systematic approaches and scientific conventions

Sam collects and records simple data from his observations using a simple (concrete materials) key.

### Progress Indicator Developing and Communicating Scientific Understanding

#### Using scientific vocabulary

Sam explores and uses new vocabulary and uses it to label observable features when he says, "Some are smooth, but some of them are serrated ... They have little prickles on them, like a saw."

#### Reflecting on their understanding

Sam is aware of changes in his own understanding: "I thought there would be more smooth leaves, but there were nearly as many serrated ones."

## **1(c) Terms used in matrix**

### **Aspects**

Aspects are the identified key aspects or goals of learning in science. Each of the four matrices has specific aspects or goals of learning. These goals describe the concept, such as Developing and Communicating Scientific Understandings (Matrix D) and are the expected learning outcomes for students.

### **Progress Indicators**

Progress indicators are the growth over time of each of the aspects, related to the Levels of *Science in the New Zealand Curriculum* (levels 1- 5). They provide a notion of the next learning step for students and can be used as criteria against which to judge student's achievement.

# Appendix 2 – Examples of Field Notes

## 2(a) Observation Notes (Year 3 and 4 students, T4)

<p>Needed to fill it in. Chr then continued to explore (1.1.10) after combinations) or fill in to investigate before also to time</p> <p>Group of boys really excited at 10 reactions (exploding) or thought it would go explosive or get worried but still kept going. Teacher questioned Chr - what happened here</p> <p>B: It all went fizzy &amp; exploded</p> <p>F: So what numbers did you use</p> <p>F: So what substances do you think they are</p> <p>B: F: is an acid because it is a liquid</p> <p>F: So what is to call one</p> <p>F: I think it is a carbonate why do you think that?</p> <p>Get out to start with to information about what causes reactions - then decides on</p> <p>F: I have a question - has anyone discovered an alkaline that didn't have a reaction?</p> <p>Flora: no - one had. Too busy mixing acid &amp; alkali.</p> <p>F: I've noticed about 2 acids. Chr then tried different substances.</p> <p>F: Two carbonates together - what happened</p> <p>F: Nothing - only get water</p>	<p>Chr collecting data</p> <p>exploded</p> <p>excited chr</p> <p>getting chr to clarify their thinking using knowledge.</p> <p>Chr refer back to info answer / reason already have</p>	<p>What else happened</p> <p>So what substances have we got</p> <p>F: An acid &amp; don't know about 10 other or</p> <p>Teacher got to check list of what happens mix acid &amp; carbonate, alkaline &amp; carbonate</p> <p>lets stop to class &amp; see if they can help</p> <p>we have a question for good scientific brains - explained what had happened - wanted chr to give ideas</p> <p>They could be both acids</p> <p>B: They could be both alkalines</p> <p>F: They could be alkalines because not powders</p> <p>B: D.K. must be acid &amp; don't get a reaction.</p> <p>Teacher compliments on chr &amp; fair scientific thinking</p> <p>F: What have other people discovered</p> <p>Chr shared what they had done - all to this trying to determine whether acid, carbonate, alkaline &amp; why they got to reaction.</p> <p>One group has two acids (orange &amp; purple) - they have settled into layers: Chr want to know why</p> <p>Teacher 'noticed' that when</p> <p>Instead of 2nd sheet</p> <p>gas state, change (color) reactions</p>	<p>Chr sharing ideas, getting other way from chr.</p> <p>Teacher</p> <p>Challenging chr.</p> <p>highlight scientifically</p> <p>Select. Imp. to respond to what will add to learning or to a distraction minimize</p> <p>vol. 1. N.O.</p>
--	--	---	---

## 2(b) Notes from discussions at Intervention

<p>Indicate why after discussion 22/6</p> <p>Screens:</p> <ol style="list-style-type: none"> <li>1. That unit not developing with chs questions as did previous unit</li> <li>2. Difficult trying to get chn to understand the basic concepts - heat going out of room into cold</li> <li>3. While they have had a plan they seem to be picking up ideas from chn or developing these ideas rather than just following thru to plan - still around the basic concepts but pick up other ways of getting chn to think about the concepts</li> <li>4. Uncomfortable with the skills - processes, don't know what to assess - skill looking for an "end-point" assessment. They thought it would be difficult to test chn's knowledge - so what would they do</li> <li>5. Raised the matrix indicators or aspects as assessment criteria - thought about it a decided that they could make statements about their investigative skills</li> </ol> <p>Discussed other activities - natural progression towards insulation - will look at keeping things warm/cold. Might do ice activities &amp; let chn decide the "tests" or make suggestions. Discussed the notion of letting chn have a little more independence - would</p>	<p>not spending facts.</p> <p>More emphasis on investigations - to "do" - usually go straight to books - get to info.</p> <p>Teachers do reading, then give chn experiences to develop their knowledge.</p> <p>Heat - did investigations, hardly looked at books</p> <p>allowing chn to develop strategies</p> <p>Find out about chn thinking - thinking a problem-solving</p> <p>Chn loved the science - give a wonder</p> <p>now make it fun, interesting</p> <p>chn "doing" it - thinking follows</p> <p>didn't use to tell science just talked about a topic</p> <p>Chn or parents bringing books to school.</p> <p>questioning - probing/clarifying - getting chn to explain - challenging knowing the knowledge or not</p> <p>selecting to appropriate activity (may have to adapt even)</p> <p>More thinking of what learning a not doing</p> <p>Becoming more selective about activities - densely textured learning</p> <p>working collaboratively - great - can get ideas to get used to needs of chn</p>
<p>Using formative ass to determine unit progression - direction</p> <p>Matrix as criteria for assessment</p> <p>Teachers knowledge needs developing</p>	<p>Teacher target</p>
<p>21</p>	<p>27</p>

## Appendix 3 - Core questions asked at the interviews

At the beginning of each session the teachers were first asked: How have things gone? What have been the highlights for you and the students? After the teachers had shared what was 'on-top' for them the researcher then used the following questions, to aid teachers' reflective processes:

- Has the matrix and exemplar made a difference to teaching and learning in science?
- What are their changes for you and the children in teaching and learning in science? What has caused these changes?
- What did you specifically focus on during the unit?
- How well did you achieve your learning intentions?
- What were the outcomes for the students?
- What factors influenced these outcomes?
- What things hindered or helped you during the unit?
- What changes have occurred in your attitude towards the teaching of science?
- What is the next step for you?
- How are you going to achieve that?
- Have the exemplars and matrix provided ideas for 'what to notice' when students are engaged in science?
- Which aspects of the matrix did you have in your head?
- As you interacted with the children what were you trying to encourage?
- What is the next step for the class and some individual students?

# Appendix 4 - Examples of transcript analysis

**Outcomes: Students:**

- Excitement around telling a ling.
- Thinking as scientists.
- Interest, attitude | excitement
- Individuals improving
- Transferring info to other ling areas.
- Scientists know immense | deep ling
- Chn working collaboratively | talking | sharing.
- Inquiring minds | thinking.
- ask questions
- predictions
- independent liners
- Chn confidence
- doing things at home
- apply know, see patterns etc, listen to other chn/ideas, trial ideas

**Outcomes: Teachers:**

- Confidence "science"
- know about what a how to teach
- scientifically developed
- see students as individuals - not a class!
- earnings about matrix in steps
- transferring to other telling experiences
- learning areas
- questioning improved
- excitement around telling a ling
- Teachers don't have to have all answers
- interest, attitude | thinking as scientist
- being specific about what to teach
- tried pathways for telling a ling
- Talk from plan - focussed plan
- Better at selecting aspects

**Critical Factors:**

- Observation
- Planning a support
- HL | SC -
- Referring to what learning
- real experience
- small gap = easier to assess
- Model of develop
- reflective
- Teachers challenging each other

**Changes:**

- Don't need old matrix anymore
- Fewer activities | in depth.
- Discussions (PPT)
- about how to teach | not what.
- Building culture of ling
- parents | teachers | chn.

**Using Planning** - indicators | aspects provides pathway at beginning of unit scope

**Leveling** - what specific aspects look-like (stds)

Progression = children | achieve

Develop | teacher know.

Focus for telling

Information about unbalanced aspects - what a how to tell.

next step for chn

overall progression for recording

indicators give direction.

To guide telling rather than measuring chn

- indicators as pathway.
- Teachers challenge each others expectations | understanding using writing as criteria
- talk about what ling

**Telling strategies** - real experiences - exploring first.

- link to prior know
- links to other ling areas
- more (existing)
- more time
- more discussion
- message from activities
- fewer activities
- modelling book
- show in learning w

**Matrix**

- put matrix up for chn.
- Plan to 'age' level but aware of before & after
- Coverage over 2 yrs?

**Matrix D - Develop | know**

- Investigating | great - context
- ask questions
- curiosity | languaging
- observing | sharing
- explaining
- social issues | tension
- one wonder
- scientific vocab
- Comparing
- Suggesting | explain
- Thinking as scientist
- Recieve tacit know
- Uncertainty of data

**Issues**

- Recording - what, how, when
- knowing critical aspects | indicators
- anecdotal notes - is this evidence
- Recording each child against
- Checklist mentality

**Exemplar**

A guide | trigger less input as been familiar with matrix

**Assessment**

- Overall progression for recording - indicators provide detail - next-step
- Recording an issue
- Collect data overtime - not one-off situation
- Matrix as criteria
- know what to notice
- easy to determine chn needs
- indicators of those whole unit - not one off
- Report to parents using indicators
- more accurate
- Schoolwide moderation

School: Ft teacher: 4  
Cycle: 3 P12113-

W/C/S	Matrix	Exemplars	Learning Strategy	Assessment	Issues	Teacher
Developing tchr know. about 'science', Focused about skills Indicators provide next-step context knowledge hinge	Reporting Communicating or interpreting	Planning Jokers - role playing - a single-focusy crab Questioning as a model - open-ended Used next-step notion Notion of quality - Set expectations for Level 2 Assess. strategies - before a tchr view Depth not coverage	Writing about crab Developing charts of knowledge - what we know. L1   SC Parents asking chn about after views. Before after - rock pools, crabs Densely - textured lining Teacher a learner Answering chn questions Chn asking questions Real experiences Viewfinders - for questioning Making crab	Reporting - collected info this unit in a variety of ways leveling chn Progression in unit - to next level Indicates next-step Identified next-step for next unit - progression. Assessable L1   SC - knowledge Summative notion of assess Variety of opportunities over unit Assessed chn on reporting, communicating, interpreting Identified next-step   progress for unit 2 Parent helps interview chn about assess. Skills not just knowledge Summative tasks are application of knowledge. report comments from indicators - criteria for assess. - indicators = aspects Called data overtime   not a one-off activity for value - provides next-step for unit a activity variety of assess. methods assess. by observation - listening, headnote taking flow assess. data	Focused on 2 aspects - but how many Levels in Matrix   Curriculum How to use matrix - has much support from tchr for chn independent. Progression using matrix Formative Assessment How will content influence matrix Differences b/w indicators, esp in co-structing, communicating, explan. Need more indicators Content dependent indicators abstract, idea based notion of progression - what level interpretation of indicators - consistency rationally need to be organised good resources CRITICAL FACTORS Reflecting on chn learning Teacher know (score) Support along the way Collaborative support	Had to tch other skills - reporting Tchr knowledge developing - especially context bias of vocab Chn a teacher loved unit Tchr learning with chn Developing 'science' knowledge - usually tchs content only Teacher needs more know. in order to ask good quest Critical Factors Team discussion Collaborative support P.D. a facilitator support Cycle - 1 reporting / modifying experience to get understanding know what to teach collected data over unit teaching flow assess. data densely textured learning teacher enthusiasm joined know flow matrix using variety of aspects   2 wks. know about levels developing know what to notice assess chn doing it focused teaching questions to really understand chn thinking / understanding
Sc. vocab Reporting Communicating or interpreting	Investigating ideas teaching ideas how to get chn to next-step matches big ideas or aspects transfer about diff contexts	L1 - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Shows what chn actually do Bdy's expectations - compared our class expect exemplar Jokers for reporting Develops tchr knowledge Next step (idea flow during unit) Before after views used vocab in daily view Taking ideas used to try understand aspects indicators Exemplar matrix of hand a hand	LI - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Progression from matrix to timeline - notes selection on unit progress Communicating aspects using matrix - use diff b/w indicators Understanding aspects a learning chn - exemplar deal along step leads difficult on timeline use of current progression - does this help What does reporting mean Interpretation of indicators School-wide focus   state what coverage - taking a series of	Reporting - reporting Tchr knowledge developing - especially context bias of vocab Chn a teacher loved unit Tchr learning with chn Developing 'science' knowledge - usually tchs content only Teacher needs more know. in order to ask good quest Critical Factors Team discussion Collaborative support P.D. a facilitator support Cycle - 1 reporting / modifying experience to get understanding know what to teach collected data over unit teaching flow assess. data densely textured learning teacher enthusiasm joined know flow matrix using variety of aspects   2 wks. know about levels developing know what to notice assess chn doing it focused teaching questions to really understand chn thinking / understanding
Sc. vocab Reporting Communicating or interpreting	Investigating ideas teaching ideas how to get chn to next-step matches big ideas or aspects transfer about diff contexts	L1 - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Shows what chn actually do Bdy's expectations - compared our class expect exemplar Jokers for reporting Develops tchr knowledge Next step (idea flow during unit) Before after views used vocab in daily view Taking ideas used to try understand aspects indicators Exemplar matrix of hand a hand	LI - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Progression from matrix to timeline - notes selection on unit progress Communicating aspects using matrix - use diff b/w indicators Understanding aspects a learning chn - exemplar deal along step leads difficult on timeline use of current progression - does this help What does reporting mean Interpretation of indicators School-wide focus   state what coverage - taking a series of	Reporting - reporting Tchr knowledge developing - especially context bias of vocab Chn a teacher loved unit Tchr learning with chn Developing 'science' knowledge - usually tchs content only Teacher needs more know. in order to ask good quest Critical Factors Team discussion Collaborative support P.D. a facilitator support Cycle - 1 reporting / modifying experience to get understanding know what to teach collected data over unit teaching flow assess. data densely textured learning teacher enthusiasm joined know flow matrix using variety of aspects   2 wks. know about levels developing know what to notice assess chn doing it focused teaching questions to really understand chn thinking / understanding
Sc. vocab Reporting Communicating or interpreting	Investigating ideas teaching ideas how to get chn to next-step matches big ideas or aspects transfer about diff contexts	L1 - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Shows what chn actually do Bdy's expectations - compared our class expect exemplar Jokers for reporting Develops tchr knowledge Next step (idea flow during unit) Before after views used vocab in daily view Taking ideas used to try understand aspects indicators Exemplar matrix of hand a hand	LI - Matrix aspect selects aspects but changes as unit change   selects more appropriate ones Using indicators to determine value of the next-step Buddy class assessing Flow assess part very thin unit to determine next step Interviewing chn Indicators for report - see next indicator assess chn based on exemplar & matrix Peer assessment in written, reporting, interviewing	Progression from matrix to timeline - notes selection on unit progress Communicating aspects using matrix - use diff b/w indicators Understanding aspects a learning chn - exemplar deal along step leads difficult on timeline use of current progression - does this help What does reporting mean Interpretation of indicators School-wide focus   state what coverage - taking a series of	Reporting - reporting Tchr knowledge developing - especially context bias of vocab Chn a teacher loved unit Tchr learning with chn Developing 'science' knowledge - usually tchs content only Teacher needs more know. in order to ask good quest Critical Factors Team discussion Collaborative support P.D. a facilitator support Cycle - 1 reporting / modifying experience to get understanding know what to teach collected data over unit teaching flow assess. data densely textured learning teacher enthusiasm joined know flow matrix using variety of aspects   2 wks. know about levels developing know what to notice assess chn doing it focused teaching questions to really understand chn thinking / understanding

# Appendix 5 - Information letters

## 5(a) Example of letter to Board of Trustees, Principals, Teachers

[ Note: a letter, similar in content to the one below, was sent to the Principal and the Board of Trustees.]

Massey Letter Head

### Project Information Sheet for ... ..... Teachers

#### Project Title

*What impact do the National Curriculum Exemplars and the associated Matrix have on teaching and learning in Science?*

#### Project Information

##### Researcher Introduction

*I am a Primary Science Adviser / Assessment Facilitator employed by the Centre for Educational Development, Massey University. I am undertaking a Master's Thesis in Education and would like to carry out my research about the National Exemplars as I work with the Junior Syndicate, in Science Education professional development. My Supervisor is Dr J M Poskitt, Director, Institute for Professional Development and Educational Research, Massey University. Ph 356 9099 Extn 8293. Jenny will work closely with me and guide the research component of my work.*

##### Participant Recruitment

- *Staff members have requested school based professional development in Science including the Science Matrix.*
- *Five teachers will be involved.*

##### Project Procedures

- *Data will be gathered through observation, questioning, discussion and interviews in association with the in school professional development programme in Science.*
- *Data will be recorded in written form (field notes) and on computer.*
- *Interviews will be audiotaped and transcribed either by me or a Massey University administrator. With the understanding that all information is anonymous and confidential.*
- *All data will be stored securely in my office at Centre for Educational Development. All computerised data will be secured by password.*
- *Findings will be shared with the participants throughout the research as part of the intervention associated with action research. A summary will be provided and the full research project will be available to staff upon completion.*
- *The research findings will be of immediate use for the staff and students of.....*
- *The general research findings will be shared with advisory colleagues in Science and Assessment for use in their work in schools of the region.*
- *The research findings could contribute to the wider field of assessment tool development in New Zealand.*

##### Participant involvement

- *The participants will be involved in an action research project where by three Science units will be planned, implemented and evaluated with a clear focus on using the*

*matrix to focus on student achievement. I will be providing professional support throughout in my Science Adviser's role.*

- *The action research cycle will be as follows:*
- *Introduction to the Matrix and the Exemplars*
- *Planning session for the unit of work*
- *In-class observation*
- *Intervention – feedback to teachers, determining next-step in the unit*
- *In-class observation*
- *Reflection and feedback*
- *Interview, setting up the next-step*
- *Teacher participation will be more intensive than that expected of a school development. Teacher interviews will be more structured and require more time. Teachers will be asked to keep a reflective journal. In all other respects, the expectation and time will be that required for quality professional development.*

### **Participant's Rights**

*Statement of rights includes:*

*You have the right to:*

- decline to participate;
- decline to answer any particular question;
- withdraw from the study at any time;
- ask that the audiotape be turned off at any time during the interview;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

### **Project Contacts**

You are invited to contact me or my supervisor at any stage to seek clarification on any matters.

This project has been reviewed and approved by the Massey University Human Ethics Committee, Palmerston North. Application 04/64. If you have any concerns about the conduct of this research, please contact Professor Sylvia V Rumball, Chair, Massey University Human Ethics Committee: Palmerston North, telephone 06 350 5249, email [humanethicspn@massey.ac.nz](mailto:humanethicspn@massey.ac.nz).

## 5(b) Example of Consent Form

[ Note: A similar consent form was signed by the  
the Principal and the Board of Trustees. ]

Massey Letterhead

### **Consent Form Teacher Participation**

#### **Project Title**

*What impact do the National Curriculum Exemplars and the associated Matrix have  
on teaching and learning in Science?*

THIS CONSENT FORM WILL BE HELD FOR A PERIOD OF FIVE (5) YEARS

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I may withdraw from this research project at any point.

I agree to participate in this study under the conditions set out in the Information Sheet.

I agree / do not agree to the interview being audio taped.

**Signature:** ..... **Date:** .....

**Full Name – printed:** .....

## Appendix 6 - Collation of data from individual interviews

### Cycle One

<b>Matrix</b>	<b>Exemplars</b>	<b>Using</b>	<b>Teacher knowledge</b>	<b>Issues</b>
<ul style="list-style-type: none"> <li>•Variety of ways to use matrix</li> <li>• Indicators inherent in the activities</li> <li>• Indicators identified differences between children</li> </ul>	<ul style="list-style-type: none"> <li>•Are a model for               <ul style="list-style-type: none"> <li>-Planning ideas</li> <li>-Teacher-pupil conversations</li> <li>- Questioning</li> <li>-Teaching strategies</li> <li>- Next-step learning</li> <li>-Assessment strategies</li> </ul> </li> <li>• Standards and expectations are explicit</li> </ul>	<ul style="list-style-type: none"> <li>•Comparing student work against exemplars – raised teacher expectations</li> </ul>	<ul style="list-style-type: none"> <li>•Provides overview of science</li> </ul>	<ul style="list-style-type: none"> <li>•Time</li> </ul>

<b>Formative assessment</b>	<b>Standards and expectations</b>	<b>Data collection</b>	<b>Student achievement</b>	<b>Teacher focus</b>
<ul style="list-style-type: none"> <li>•Learning goals shared with the children</li> <li>• Reflecting on children's knowledge and development</li> <li>•Know what to notice, provide next-step</li> <li>•Responding to students' learning during unit</li> <li>•Notion of progression</li> </ul>	<ul style="list-style-type: none"> <li>•Standards and expectations raised</li> <li>•Moderating student work against exemplars</li> <li>•Notion of quality developing</li> </ul>	<ul style="list-style-type: none"> <li>•What information should be collected and how should it be recorded.</li> </ul>	<ul style="list-style-type: none"> <li>•Development of knowledge</li> <li>• Using Scientific vocabulary</li> <li>• Thinking is developing</li> <li>•Students motivated</li> <li>•Parental interest due students' enthusiasm</li> <li>•Skills developing</li> <li>•Students have a bigger view of science</li> </ul>	<ul style="list-style-type: none"> <li>•Focus on all children succeeding</li> </ul>

**Table 3: Teacher Pedagogy**

Planning	Teacher confidence	Co-construction	Teaching strategies	Teacher knowledge
<ul style="list-style-type: none"> <li>• Learning outcomes are more focused</li> <li>• Activities support the learning</li> <li>• Densely textured learning occurring</li> <li>• Depth not coverage</li> <li>• Focused concepts narrower focus</li> <li>• Units more focused on development of skills and attitudes</li> <li>• Importance of real experiences</li> </ul>	<ul style="list-style-type: none"> <li>• Teacher enthusiasm and confidence growing</li> <li>• Teachers attitude to science changing - positively</li> </ul>	<ul style="list-style-type: none"> <li>• Development of children's thinking</li> <li>• Need for children to engage in talk</li> <li>• Children need research skills</li> </ul>	<ul style="list-style-type: none"> <li>• Teaching strategies varied and support the learning outcomes</li> <li>• Promote student thinking</li> <li>• Students developing deep understanding, not coverage.</li> <li>• Questioning skills vital and need improving</li> </ul>	<ul style="list-style-type: none"> <li>• Awareness of the need for transfer of new skills to other learning areas</li> <li>• Notion of standards</li> <li>• Assessment practice developing</li> <li>• Teachers asking how to improve outcomes for students</li> <li>• Overview of science developing</li> </ul>

**Table 4: Professional Development Model**

- Changed the way the teachers work together in School B
- The nature of the discussions - teacher talk about practice and student learning

## Cycle Two

**Table 5: Teacher interaction with the Exemplars and Matrix**

Matrix	Exemplar	Using	Teacher knowledge	Issues
<ul style="list-style-type: none"> <li>• Matrix explains how and what to teach – ie investigating</li> <li>• Matrix and exemplars are a package</li> </ul>	<ul style="list-style-type: none"> <li>• Less use of exemplars – just ideas for teaching strategies e.g. graphing</li> <li>• Exemplar helps determine a standard</li> </ul>	<ul style="list-style-type: none"> <li>• Changing aspect during unit if not appropriate</li> <li>• Aspects – determine activities inherent in activity provided context dependent</li> <li>• Using more indicators and aspects in the planning</li> </ul>	<ul style="list-style-type: none"> <li>• Aspects becoming clearer as see children's work</li> <li>• Matrix more helpful as become familiar with it</li> <li>• Some aspects and indicators becoming tacit, so developing new aspects</li> </ul>	<ul style="list-style-type: none"> <li>• Some aspects and indicators - hard for young children</li> <li>- not clear</li> <li>• Indicators don't differentiate between levels enough</li> <li>• Some aspects too big – don't have enough detail and open to interpretation</li> </ul>

**Table 6: Teacher Assessment Practice**

<b>Formative assessment</b>	<b>Data collection</b>	<b>Standards and expectations</b>	<b>Student achievement</b>	<b>Teacher focus</b>
<ul style="list-style-type: none"><li>•Prior knowledge collected and used</li><li>•Know what to notice</li><li>•Planning from data collected</li><li>•Variety assessment methods and opportunities</li><li>•Using assessment formatively: finding the next-step, changing activities</li><li>•Observe and talk to children to elicit understanding</li><li>•Self &amp; peer assessment against aspects &amp; indicators</li><li>•Matrix indicators as LI/SC, shared with children</li></ul>	<ul style="list-style-type: none"><li>•Collect data over time</li><li>•Concern with school-wide data</li><li>•Using assessment for summative purposes- reporting, but not exclusively</li><li>•Teachers more concerned with progression over time</li><li>•How and what to show progression in an issue</li></ul>	<ul style="list-style-type: none"><li>•Developing notion of levels</li><li>•Determining a standard and expectation – exemplar helpful</li><li>•Developing notion of progression</li><li>•Using matrix to see where children are at and providing the next-step during the unit</li></ul>	<ul style="list-style-type: none"><li>•Children seen as individuals</li><li>•Children thinking and working scientifically</li><li>•Children reflect on their learning and evaluate their thinking</li><li>•Deeper learning -Learning not just about knowledge</li><li>•Outcomes for children have changed – thinking and explaining, changing their minds and opinions</li><li>•Parents getting involved.</li></ul>	<ul style="list-style-type: none"><li>•Focussed on what children learning</li></ul>

**Table 7: Teacher Pedagogy**

Planning	Teacher confidence	Co-construction	Teaching strategies	Teacher knowledge
<ul style="list-style-type: none"> <li>•Planning flexible –, not fully developed, check daily that ideas/ activities are appropriate</li> <li>•Matrix aspects developed unit to unit. Revisit some aspects over the year</li> <li>•Science not just in science time</li> <li>•Densely textured learning, revisiting activities, fewer activities, and narrower content focus.</li> <li>•Planning focused, organised, depth not coverage</li> <li>•Including more aspects and indicators overtime</li> <li>•Plans questions before lessons</li> </ul>	<ul style="list-style-type: none"> <li>•Teacher enthusiasm and confidence increasing</li> <li>•Doesn't give up on teaching science,</li> </ul>	<ul style="list-style-type: none"> <li>•Determining and building on prior knowledge</li> <li>•Layering of information, making links to prior knowledge</li> <li>•Students talking and sharing thinking/ideas</li> <li>• Students becoming more responsible for finding their own answers – not relying on teacher to solve everything</li> <li>• Children know where they are going and how to get there. They review their learning and add onto it.</li> </ul>	<ul style="list-style-type: none"> <li>• Revisit original thinking, see whether they have changed their thinking and why</li> <li>• More assessment strategies used</li> <li>• Changing: more discussing, reflecting on understanding, sharing and explaining and investigating</li> <li>• Children allowed more independence</li> <li>•Teachers reflect on matrix at end of the unit and can identify the science way of working</li> <li>• Not so knowledge based</li> <li>• Questions focused around matrix and indicators – probing, expect explanations and justifications</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge about science / nature of science developing</li> <li>•Teachers accepting uncertainty</li> <li>• Assessment strategies improved</li> <li>•Better at selecting appropriate aspects</li> <li>• Children seen as individuals</li> <li>• Growing accountability for student achievement</li> <li>•Increased awareness of questioning, conversations and the influence on students learning</li> <li>•Understanding of matrix developing</li> <li>•More aspects covered, many tacit</li> <li>•Greater expectation of achievement</li> </ul>

**Table 8: Professional Development Model**

- Professional support is critical
- Equipment and resources and new activities are really helpful
- Help when stalling is essential
- Providing Science knowledge and pedagogy has helped
- Planning has made all the difference
- Collaboration critical
- Team discussion
- Reflecting on practice

## Cycle Three

Matrix	Exemplar	Using	Teacher knowledge	Issues
<ul style="list-style-type: none"> <li>Aspects shape the way teachers teach and are inherent in activities</li> <li>Matrix provides pathway and expectations</li> <li>Context dependent</li> <li>Indicators about teaching and learning</li> <li>Clarifies teachers thinking</li> <li>Provides a framework for students' learning</li> <li>Include several aspects in planning</li> </ul>	<ul style="list-style-type: none"> <li>Provide an expectation</li> <li>Not used this time</li> <li>Exemplars up skill teachers, model teaching ideas</li> <li>Clarify teachers thinking</li> <li>Provides a framework for students learning</li> <li>Explain the differences between the levels and what the indicators and aspects mean.</li> </ul>	<ul style="list-style-type: none"> <li>Not restricted by planned indicators and aspects, change if need to</li> <li>Uses matrix to reflect on practice-when things go wrong, during and at the end of a unit.</li> <li>When planning new unit</li> <li>Older children to begin use matrix to determine pathways</li> <li>Moderate students work using exemplars and the matrix</li> </ul>	<ul style="list-style-type: none"> <li>Better at selecting aspects and indicators</li> <li>Challenges teachers</li> <li>Teachers' understanding of a standard and expectation is developing</li> <li>Many indicators and aspects tacit knowledge</li> </ul>	<ul style="list-style-type: none"> <li>Some aspects and indicators not clear</li> <li>Are there some key aspects for school wide coverage</li> <li>Confusion over how many aspects to cover</li> </ul>

Formative assessment	Data collection	Standards and expectations	Student achievement	Teacher focus
<ul style="list-style-type: none"> <li>Peer assessment</li> <li>Modify activities based on data collected</li> <li>Assessing knowledge and aspects</li> <li>Concern with school-wide progression and coverage</li> <li>Use indicators and aspects for reporting</li> <li>Uses assessment formatively – changes plan in light of evidence and data collected</li> <li>Assessment more accurate as know what to notice</li> </ul>	<ul style="list-style-type: none"> <li>Report to parents and children using indicators and aspects</li> <li>School-wide data collection under consideration.</li> <li>What and how much data to collect</li> <li>What data is the most helpful</li> </ul>	<ul style="list-style-type: none"> <li>Moderation of students' work – class, syndicate, and against exemplars.</li> <li>Teachers aware of indicators before and after appropriate level – can then provide the next-step</li> <li>Developed ideas of standards, and the differences between levels</li> </ul>	<ul style="list-style-type: none"> <li>Thinking improving</li> <li>Change minds in the light of new evidence</li> <li>Accept uncertainty</li> <li>Students motivated</li> <li>Increased understanding of the concepts and the nature of science</li> <li>More independent in trialling and exploring</li> <li>Students reflect on their learning</li> <li>Know what they are learning</li> <li>Students transfer learning to other situations</li> </ul>	<ul style="list-style-type: none"> <li>Matrix provides the next-step, provides extension for students</li> <li>Not restricted by planned aspects, change if need to</li> <li>Revisits matrix at end of unit – what has been covered, what gaps exist</li> <li>Seeing children as individuals</li> <li>More knowledgeable about student achievement</li> <li>Notion of progression in student achievement</li> <li>Doing more science</li> </ul>

**Table 11: Teacher Pedagogy**

Planning	Teacher confidence	Co-construction	Teaching strategies	Teacher knowledge
<ul style="list-style-type: none"> <li>•Planning is explicit and has focused teachers' teaching.</li> <li>•Select activities that link to children's learning</li> <li>•Densely textured learning</li> <li>•Real experiences and hands on</li> <li>•Planning is organised and resourced through out the unit</li> <li>•Activities support the learning intentions and success criteria</li> <li>•Fewer activities</li> </ul>	<ul style="list-style-type: none"> <li>•Teachers are motivated</li> <li>•Teacher as a learner</li> <li>•Teachers looking at own effectiveness and teaching</li> <li>•More responsible for students learning</li> <li>•Teachers' talk is different – more scientific</li> <li>•Teachers are enthusiastic and motivated</li> </ul>	<ul style="list-style-type: none"> <li>•Challenging children</li> <li>•Teacher and children co-constructing understandings.</li> <li>•Students challenging each other</li> <li>•More discussions about thinking and learning</li> <li>•Share learning with students</li> <li>•Teacher as a learner</li> <li>•Change minds in light of new evidence</li> </ul>	<ul style="list-style-type: none"> <li>•Sharing learning and learning process with children</li> <li>•Allowing more independent trialling and exploring</li> <li>•Deliberate teaching and appropriate strategies</li> <li>•Variety of activities but revisiting to ensure depth of understanding</li> <li>•Science not just a lot of episodes, links from unit to unit</li> <li>•Students' needs driving teaching</li> <li>•Prior knowledge used</li> <li>•Integrating science into other curriculum areas,</li> <li>•Changing practice to allow children to develop ideas and thinking</li> </ul>	<ul style="list-style-type: none"> <li>•Matrix is focus for learning</li> <li>•Aspects, indicators becoming tacit</li> <li>•High expectations of all students</li> <li>• Indicators driving teacher questions, questioning improved</li> <li>•Changed teaching strategies</li> <li>•Knowledge of science concepts and the nature of science improved</li> <li>•Assessment strengthened</li> <li>•Selecting more appropriate aspects and indicators</li> <li>•Selecting important goals in science</li> <li>• Accepting uncertainty in science – do not expect to have all the answers</li> </ul>

**Table 12: Professional Development Model**

- Critical to work together, planning and supporting each other with ideas and resources
- Collaboration and talk about practice
- Resources and equipment – from the researcher and each other
- Facilitator / researcher support
- Reflective practice
- Observations
- Planning

## Cycle Four

**Table 13: Teacher interaction with the Exemplars and Matrix**

Matrix	Exemplar	Using	Teacher knowledge	Issues
<ul style="list-style-type: none"> <li>•Not using overall progression</li> <li>•Matrix A not used</li> </ul>	<ul style="list-style-type: none"> <li>•Exemplar not used this time as standards becoming clearer.</li> <li>•Didn't need activities or strategies</li> </ul>	<ul style="list-style-type: none"> <li>•Aspects to structure activities</li> </ul>	<ul style="list-style-type: none"> <li>•Don't look at next –step, confident to set own</li> <li>•More aspects covered each time – many tacit</li> </ul>	<ul style="list-style-type: none"> <li>•Context dependent</li> <li>•Still struggling with some aspects</li> </ul>

**Table 14: Teacher Assessment Practice**

Formative assessment	Data collection	Standards and expectations	Student achievement	Teacher focus
<ul style="list-style-type: none"> <li>•Know what to notice</li> <li>•Provides the next –step</li> </ul>	<ul style="list-style-type: none"> <li>•School-wide data collection and progression an issue</li> <li>•How to record an issue</li> </ul>	<ul style="list-style-type: none"> <li>•Better notion of levelling</li> <li>•Progression clearer – within an aspect and across aspects</li> </ul>	<ul style="list-style-type: none"> <li>•Achievement raised, meeting higher expectations, deep learning</li> <li>•Thinking developing</li> <li>•Bigger idea of science</li> <li>•Parents involved</li> <li>•Motivated: know what they are learning and how to get there</li> <li>•Making choices / trialling/ collecting data purposefully</li> <li>•Have criteria and reflect on their learning</li> <li>•More ownership of their learning</li> <li>•Apply and transfer knowledge, refer back to it</li> </ul>	<ul style="list-style-type: none"> <li>•Children are seen individuals</li> </ul>

**Table 15: Teacher Pedagogy**

Planning	Teacher confidence	Co-construction	Teaching strategies	Teacher knowledge
<ul style="list-style-type: none"> <li>• Check daily that ideas/ activities are appropriate</li> <li>• Deliberate acts of teaching</li> <li>• Planning flexible – a number of pathways, but not fully developed as need to see way children develop</li> <li>• Real experiences</li> <li>• Densely textured learning</li> </ul>	<ul style="list-style-type: none"> <li>• Teachers really enjoying science</li> <li>• More confident</li> </ul>	<ul style="list-style-type: none"> <li>• Students can reflect on learning, change minds, challenge each other.</li> <li>• Teachers challenge children's thinking</li> <li>• Move from research to investigating</li> </ul>	<ul style="list-style-type: none"> <li>• Review learning and add onto it</li> <li>• Indicators as LI</li> <li>• Revisit and change activities: more mileage from activities,</li> <li>• Better organised, think through management</li> <li>• Focused and explicit teaching</li> <li>• Assessment strategies improved</li> <li>• Students know where they are headed and how to get there</li> <li>• Lifted teacher expectation about of achievement</li> </ul>	<ul style="list-style-type: none"> <li>• Matrix aspects developed unit to unit</li> <li>• Revisit some aspects over the year</li> <li>• Matrix guides questions, so can challenge children</li> <li>• More aspects covered, many tacit</li> <li>• Review matrix at end of each unit</li> <li>• Teachers accepting uncertainty</li> <li>• Better at selecting appropriate aspects</li> <li>• Teacher knowledge of science / nature of science developed</li> <li>• Increased accountability for student achievement</li> </ul>

**Table 16: Professional Development Model**

- Professional development is critical
- The action research model has been critical - observation, intervention, reflection
- Planning
- Working Collaboratively

# Appendix 7 - Planning format sample

Context:		Duration:	
Achievement Objectives:			
Big Science Ideas:		Matrix Aspects:	
<ul style="list-style-type: none"> <li>•</li> <li>•</li> <li>•</li> <li>•</li> <li>•</li> </ul>		<ul style="list-style-type: none"> <li>•</li> <li>•</li> <li>•</li> <li>•</li> <li>•</li> </ul>	
Learning Intentions	Success Criteria	Learning Activities	Assessment - Notes to Inform Teaching and Learning

Learning Activities	Learning Intention	Specific Learning Outcomes	Notes to Inform Teaching and Learning
Resources:			