Teaching Primary Science

Trial-teacher feedback on the implementation of Primary Connections and the 5E model

Australian Government

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Foreword

The Australian Academy of Science is proud of its long tradition of supporting and informing science education in Australia. *Primary Connections: linking science with literacy*, its flagship primary school science program, is making a real difference to the teaching and learning of science in Australian schools.

Primary Connections has been developed with the financial support of the Australian Government and has been endorsed by education authorities across the country. The Steering Committee, comprising the Department of Education, Employment and Workplace Relations and Academy representatives, and the Reference Group, which comprises representatives from relevant stakeholders including all state and territory education jurisdictions, have provided invaluable guidance and support. Additionally, before publication, the teacher background information on science is reviewed by a Fellow of the Academy with specific expertise in the topic. All these inputs have contributed to developing a quality program.

Teacher feedback has been an important part of the program's developmental process. Adjunct Professor Keith Skamp has drawn on an extensive and rich data source of written feedback. This includes data from 206 teachers, collected over more than six years of implementing trial curriculum units. We are indebted to these teachers for their contribution to the development of the program.

The Skamp Report provides firm evidence for the effectiveness of the Primary Connections program. It describes significant gains, particularly in enhancing teachers' confidence and skills. This, in turn, has impacted positively on students' learning and interest in science. It is gratifying to hear of the emergence of a 'passion' for teaching science at the primary level.

This report has been made possible thanks to the support of the Australian Government. We anticipate that the findings will be an invaluable resource for the wide range of education professionals—teachers, professional learning providers, curriculum resource writers and policy decision makers—who play a vital role in supporting the teaching and learning of science.

Professor Suzanne Cory, AC PresAA FRS
President
Australian Academy of Science

Executive Summary

The aim of this research project was to enhance knowledge of how teachers understand and implement Primary Connections units, in particular the enhanced 5E learning cycle. It is based on extensive written feedback from over 200 sets of responses from teachers who trialled Primary Connections units between 2005 and 2012. This feedback contained approximately 3000 teacher statements referring to the strengths and weakness of a range of aspects related to the implementation of the trial units.

A content analysis of teacher feedback on 16 trial units was completed. Four units from each of four science content strands* and four different levels of primary education were selected. The analysis searched the feedback from 206 teachers for evidence that the purposes for each phase of the 5E model were addressed in teachers' implementation of the unit. The data were also searched to determine whether various teacher and student roles associated with implementing science from constructivist, inquiry, language and assessment perspectives were present. These analyses provided a range of insights into how these teachers perceived the implementation of Primary Connections units. Inductive analytical processes were used to discern any emerging issues in the teachers' feedback that would provide additional insights into the implementation of the units and their impact on the teachers.

The analyses have provided a rich data source of teachers' perceptions and self-reports that have been categorised and interpreted using the above processes. The detailed and extensive findings from these data will inform policy decisions that underpin future professional learning initiatives and the development of curriculum support materials associated with the effective implementation of Primary Connections units and the enhanced 5E learning cycle. A key audience for this report is, therefore, the Primary Connections team. However, the expectation is that enacting the recommendations in this report will improve classroom teaching and enhance students' scientific literacy and their interest and learning in science. This is the goal of all involved in science education, from the Australian Government to the classroom teacher.

Responding to research questions underpinning this project has resulted in findings, insights and recommendations that are very specific. However, at a broad level, teachers' feedback indicates that Primary Connections has had a very real and positive influence on most (if not all) responding teachers' thoughts about the nature of inquiry-oriented and constructivist-based science learning at the primary level, as in the 5E model. Also, it would appear that these perceptions have been realised, to varying degrees, in many classrooms. There was, in many of these teachers' responses, a 'passion' for teaching science at the primary level: it 'oozed' through a range of their comments.

The research literature reviewed for this project indicated that a critical factor in encouraging teachers to persist in teaching constructivist and inquiry-orientated science is *to keep trying to teach in these ways*. The specific findings from this project will assist teachers at various points in their professional journey towards 'becoming science teachers', and help them to persist in their efforts.

This research project found that across the whole sample of trial teachers all the purposes of the separate 5E phases were met, and there was evidence that opportunities were provided for students to fulfil virtually all of the various learning roles associated with a range of perspectives on teaching and learning science. Whether any individual teachers met all these expectations is not known, but the research project has raised a number of issues

* This document uses 'science content strands' to describe the four main areas of science conceptual understanding: biological sciences, chemical sciences, earth and space sciences and physical sciences. This is different from the language in the new Australian Curriculum: Science, where these categories are referred to as 'sub-strands'.

that some teachers may need to address. This also means that those involved with the professional learning of Primary Connections teachers, as well as those who develop support materials for Primary Connections, need to consider these issues.

The data does have limitations, and in reading the detailed findings, insights and recommendations, these limitations need to be kept in mind. Since the recommendations are very specific, only the categories of recommendations found in the report are listed here with one or more examples in parentheses, which the Primary Connections team should consider. Recommendations were made concerning the:

- overall 5E model (emphasise to teachers that all phases must be implemented for effective learning);
- separate phases of the 5E model (suggest ways teachers can follow-up students' questions for later investigation; ensure teachers are aware of the main science concept or understanding that students are to try to apply in new contexts in the *Elaborate* phase);
- learner roles from a range of science pedagogical perspectives (include more emphasis on how teachers can encourage students to engage in self and peer assessment); and
- conditions for effective science learning (assist teachers in making a wide range of 'Nature of Science' attributes explicit in their teaching).

For each category of recommendations there was a range of positive findings and insights. To conclude this summary, two will be mentioned. One is that teachers who had taught more than one Primary Connections unit with the same students reported positive impacts on their students' conceptual understanding and inquiry-skill development. The other is one of the emergent themes that evolved: the joy experienced in teaching Primary Connections units had a positivie impact on teachers' confidence to teach primary science. For teachers, this was in part related to their students' obvious interest in science and the impact of the units on their students' learning. Although many actions remain to be taken, Primary Connections *is* making a difference.

Professor Keith Skamp
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Introduction

Primary Connections is an innovative national initiative of the Australian Academy of Science. It has several purposes. These include improving the teaching of science in Australian primary schools and enhancing the scientific literacy of primary students. Primary Connections also aims to develop a supportive environment for students and teachers to learn and teach science.

The curriculum resources associated with the Primary Connections initiative revolve around a research-based model which guides the sequencing of students' learning experiences. This model is the 5E learning cycle (Bybee, 1997). The Model has five consecutive phases—*Engage*, *Explore*, *Explain*, *Elaborate* and *Evaluate*—each with its own specific purposes. An enhanced form of the cycle is used in Primary Connections, which has incorporated strong literacy links and which embeds assessment within the model.

Primary Connections may be considered a science education reform initiative that is encouraging teachers to embrace constructivist and inquiry-oriented pedagogies. In Primary Connections, there is a balance between personal and social constructivist emphases, and teacher and learner roles reflect this duality. The inquiry-oriented pedagogy and embedded assessment influence other teacher and learner actions. Expectations of what learners and teachers would be doing in Primary Connections classrooms, in part, underpin this research project.

1.1 Aim of the project

This research project aims to enhance knowledge of how teachers understand and implement Primary Connections, in particular the 5E learning cycle. It is based on feedback from teachers who have trialled Primary Connections units. As a consequence, the research will advance recommendations to assist in improving the further implementation of Primary Connections.

1.2 Nature of the project

This research outlines how teacher feedback from implementing Primary Connections trial units (over an extended period) will be analysed in order to provide insights about the effective teaching and learning of primary science. In particular, inferences will be drawn from teacher feedback that will assist in understanding whether Primary Connections has been implemented as intended. Research evidence connects teachers' understanding of the 5E learning cycle, and how well they implement it, with students' science outcomes and interest in science. Hence, one facet of analysing teachers' feedback was to see if the feedback reflects an understanding of the embedded 5E model and what it means to implement it. This, in part, will be an indication of the fidelity of implementation of the Primary Connections learning and teaching model.

When teachers reflect on their implementation of Primary Connections units, the strengths and weaknesses they identify also illuminate some of their beliefs about science, science teaching and science learning. Reading and analysing their comments through the various lenses of the studies overviewed in Chapter 3 will provide a wider landscape to draw upon when inferring what happened in their classrooms and seeking to understand the reasoning for what had occurred.

Implications for improving professional learning associated with Primary Connections and further development of curriculum support materials will be recommended on the basis of the findings from the above analyses.

1.3 Project context

Most of the teachers in this project have trialled one or more Primary Connections units and submitted extensive written feedback on the strengths and weaknesses of the overall sequence of a 5E unit and the activities in the lessons within each phase of the 5E learning model. They have also provided comments about the strengths and weaknesses of other aspects of the unit(s), such as the implementation of the 'word wall' and the use of an 'investigation planner'.

1.4 Significance of the project

This study is significant as it will:

- add to the limited knowledge and literature on teachers' understanding and implementation of the 5E learning cycle and associated pedagogies (and hence the Primary Connections initiative);

- provide insights that inform policy decisions underpinning future professional learning initiatives and the development of curriculum support materials associated with the effective implementation of the enhanced 5E learning cycle;
- deepen various stakeholders'[1] understanding and perceptions of effective primary science practice through its detailed analysis and commentary of teachers' feedback about implementation of the embedded 5E learning cycle.

1 The findings will be especially of value to the Primary Connections team and teachers.

Using extensive and detailed written teacher feedback (over more than a six year period) on the intervention (here, Primary Connections and its enhanced 5E learning model) to infer teachers' conceptions of teaching and learning is an approach not located in the literature. (The literature does record teachers' perceptions of the implementation of innovations but not in the extensive detail that teachers have provided for the implementation of Primary Connections.)

1.5 Report outline

Initially, this report overviews the recent research literature (mainly since 2000) that has reported on the implementation of the 5E learning cycle, as well as the introduction of innovative science pedagogy at primary level (Chapter 2). This review directly links this recent research with the purposes of the current project and how it has guided the approach taken to the research design, which is outlined in Chapter 3. Chapters 4 to 11 provide the detailed analyses and commentary related to the teachers' feedback about the implementation of trial Primary Connections units. These chapters refer to:

- the overall 5E model (Chapter 4);
- the purposes of the separate phases of the 5E model (Chapter 5);
- analyses of the feedback through various interpretive lens, namely, a constructivist perspective (Chapter 6), an inquiry perspective (Chapter 7), a 'language/talk' perspective (Chapter 8) and an assessment perspective (Chapter 9);
- an interpretation of the feedback using an evidence-based list of components associated with the effective learning of primary science (Chapter 10);
- other issues derived from teachers' comments that provide further insights into how these teachers perceived the implementation of Primary Connections units (Chapter 11); and
- a summary of the findings and insights from each of Chapters 4 to 11, and recommendations that evolve from these findings (Chapter 12).

PC FINDINGS*

Primary Connections has had a very real positive influence on most (if not all) responding teachers' thinking about the nature of inquiry-oriented and constructivist-based (as in the 5E model) science learning at the primary level.

* The 'PC Findings' are extracts from Chapter 12.

Chapter 2

Primary Connections and science education pedagogical reform

Focus: constructivist and inquiry-oriented strategies with connections to the analysis and interpretation of teacher feedback

Introduction

The major concepts and ideas which guided the analysis and interpretation of teachers' feedback about the implementation of trial Primary Connections units were those related to constructivist and inquiry-oriented science pedagogies. The main *constructivist* focus was the enhanced[2] 5E learning cycle, which underpins the sequencing of lessons within Primary Connections units. Various learner and teacher roles that characterise *constructivist pedagogies* as well as *inquiry science*, including the use and application of science inquiry skills, are initially outlined (*see* section 2.2).

These two foci are set within a broader framework of components that have been identified as supporting the effective teaching of science at the primary level. These 'components' can be related to the 5E and inquiry-oriented frameworks. Consideration of assessment and the nature of science and learning technologies are included in this broader framework (*see* section 2.3).

Research findings about teachers' understanding and implementation of the 5E model are outlined and consequent implications for practice are identified (sections 2.4 and 2.5). These will assist interpretations of teachers' reported decisions and actions in their feedback comments.

Teachers' beliefs will influence the nature of the feedback they have provided. The nature of these beliefs and their interplay with teachers' contexts are explored, together with how these beliefs could impact on constructivist and inquiry-oriented science pedagogies (*see* section 2.6).

2
The 'enhanced' learning cycle, used by Primary Connections, also stresses literacy science connections, multiple literacies and multiple representations, as well as co-operative learning strategies and embedded assessment. Socio-cultural constructivist emphases are readily apparent. *See* section 2.2 for more details.

In this overview, references are not made to earlier Primary Connections research reports. Where appropriate, key findings from these reports will be integrated into interpretations drawn from the analyses of the teacher feedback.

2.1 The 5E learning cycle

This constructivist model for planning and implementing science was the basis for the development and implementation of Primary Connections units. Although there are various versions of the 5E learning cycle, the Primary Connections model incorporates *Engage*, *Explore*, *Explain*, *Elaborate* and *Evaluate* phases. The purposes of each phase are in Appendix 2.1 (AAS [Australian Academy of Science], 2008a). They embrace personal and social constructivist learning emphases (Yore, Anderson & Shymansky, 2005), including an appreciation of the role of teacher- and student-generated-representations in learning and general and science-specific literacies. Investigating scientifically, with its emphasis on science inquiry skills, is embedded in the cycle, as are diagnostic, formative and summative assessment practices.

As it differs from teacher transmission practices, the 5E cycle has been referred to as a different pedagogical 'paradigm' (Cavallo & Laubach, 2001, p. 1035). Implementing the 5E cycle would be a pedagogical shift for teachers who have taught primary science using traditional transmission approaches, as well as for those who have used hands-on tasks, perhaps with an emphasis on some science processes such as observing but not, for example, with the intention of students constructing key conceptual understandings. This is because it requires teacher and student roles that contrast with those found in more conventional science teaching and learning. Harlen (2009) has identified these roles in her conceptualisation of a pedagogy that, she argues, will achieve scientific literacy outcomes for learners. Her pedagogy draws on four different perspectives that have emerged from research about effective science learning (*see* Appendix 2.2). These are a (personal and socio-cultural) constructivist perspective; a 'discussion, dialogue and argumentation' perspective; an inquiry perspective; and a 'formative use of assessment' perspective. The resultant list of learner and teacher roles comprehensively covers most expectations of learners and teachers in the Primary Connections enhanced 5E model.

2.11 Socio-cultural constructivist emphases in the 5E model

The Primary Connections' 'purposes' for each of the 5Es do refer to students and teachers using language to develop understandings. Harlen's (2009) learner and teacher roles, however, add additional emphases to the importance of 'forms of language' in learning science, such as classroom dialogue, reporting, open-ended questions and students listening to others' explanations of phenomena they are encountering, as well as sharing their own explanations and ideas. These, together with multi-modal expressive and interpretive communication processes, are integral to students' meaning-negotiation processes. This socio-cultural perspective on the importance of language in learning science is thought to be most helpful in advancing conceptual development and meaningful understanding (Glasson & Lalik, 1993; Scott, Asoko & Leach, 2007).

Socio-cultural emphases within the 5Es also would see students as having opportunities to participate in 'science as practice'. Science as practice has four strands[3]:

- know, use and interpret scientific explanations;
- generate and evaluate scientific evidence and explanations;
- understand the nature and development of scientific knowledge; and
- participate productively in scientific practices and discourse.

These are expanded in Appendix 2.4. This 'science as practice' perspective requires teachers to see classroom management through a different lens. Rather than perceiving the maintenance of control and management of their classrooms as separate from instruction, teachers are encouraged to use 'pervasive management' which is intertwined with learning (Harris & Rooks, 2010). This approach to management requires:

> effective scaffolding that supports students in integrating and applying ideas. Students assume more responsibility as they collaborate and communicate around authentic tasks and investigations, and participate in a community of scientific practice (p. 230).

These ('management') roles for the teacher and students overlap with Harlen's (learning and teaching) roles for effective science learning. If these management roles are practised they would assist in the implementation of the purposes of each phase in the 5E learning cycle and the establishment of a community of science practice within the classroom. Science learning would then embrace both learning as acquisition and learning as participation (Scott, Asoko & Leach, 2007). The goals of the Primary Connections initiative are consistent with pervasive management. As implied, such an approach expects students to take growing responsibility for investigating scientifically, use evidence thoughtfully and propose explanations for the data they have collected. Teachers' feedback about implementing the Primary Connections trial units will help identify student and teacher roles, and may indicate if communities of practice are developing and that management is not referred to separately from learning. Appendix 2.5 overviews the nature of, and some issues associated with, pervasive management as it pertains to the 'areas' of students, instructional materials, tasks, science ideas and the overall social context of students' inquiry learning environments—this last issue being the cornerstone of this approach to management.

In an early study, which used a sociocultural interpretation of the 5E cycle, Glasson & Lalik (1993) described the case study of Martha and how she implemented the 5E learning cycle with a language focus, gradually becoming more aware of the value of student talk and listening to students' ideas. In doing this Martha started to provide more opportunities for students to use problem solving 'to explore and elaborate their understanding' and 'to discuss and explain their conceptions'. However, Martha experienced a 'tension between efforts to provide students with information and efforts to encourage students to construct their own knowledge through dialogue' (p. 196). Tensions other teachers reported (in Glasson & Lalik's study), when using the 5E learning cycle were difficulty in eliciting students' ideas (Randy, year 9), knowing when to engage students in divergent discussion (Sally, middle school), difficulty in helping students to clarify their own understandings (Natalie, elementary), and providing adequate time for discussion and allowing students to take

3
Harris & Rooks, 2010, p. 229.

4
These findings have been replicated in related research. Grant and Kline (2000, p. 26), for example, reported that primary teachers' 'ability to elicit and engage with students' ideas and explanations of thinking was the slowest teaching practice to develop'. Suggestions to explain this observation mentioned teachers' concerns about keeping students engaged in discussions and ensuring that appropriate (correct) conclusions were reached.

control of their own learning (Helen, elementary)[4]. These findings suggest that appreciating and implementing this social constructivist interpretation of the 5E learning cycle would be a considerable shift for teachers who have perceived learning science as engaging students primarily in verification hands-on tasks or hands-on tasks which culminate in direct teacher input or even simply believing that completing activities will result in student learning (Yore, Anderson & Shymansky, 2005). Many teachers may sense the above 'tensions' as they try to implement constructivist models such as the 5Es and, consequently, their resultant classroom decisions and actions may not provide opportunities for several of the learner roles in Harlen's list.

2.2 Conditions to support effective learning of science at the primary level

In a comprehensive and large-scale study of the implementation of science in Victorian primary schools, the Science in Schools (SiS) project identified eight components that effectively support student learning and engagement in science. These are listed below and expanded in Appendix 2.3:

1. Students are encouraged to actively engage with ideas and evidence.
2. Students are challenged to develop meaningful understandings.
3. Science is linked with students' lives and interests.
4. Students' individual learning needs and preferences are catered for.
5. Assessment is embedded within the science learning strategy.
6. The nature of science is represented in its different aspects.
7. The classroom is linked with the broader community.
8. Learning technologies are exploited for their learning potentialities.

(Extracted from Tytler, 2003, p. 285)

As outlined, the pedagogical model which underpins the Primary Connections project is the constructivist-based 5E learning cycle. Its purposes may be positioned within this more encompassing framework. Most of the SiS components are evident within the cycle. Components (1) and (2) are integral to the 5E phases. Developing meaningful science understandings is a core outcome of the learning cycle, and occurs primarily through students actively engaging (physically and mentally) with ideas and evidence. This active engagement incorporates students' use of general skills (e.g., literacy skills such as listening, reading and writing), as well as science inquiry skills such as observing, predicting and testing ideas. Primary Connections encourages teachers to use an inquiry-oriented approach by embedding an aspect of the nature of science (NoS), namely investigating scientifically, in the cycle (*see* SiS component (6). The initial phase of the 5E cycle especially aims to engage students' interests (*see* SiS component (3), while assessment is embedded in all phases (*see* SiS component (5).

This list of components is therefore helpful in determining if classrooms and teachers, especially those implementing Primary Connections' units, are supporting this wider set of conditions for the effective learning of science.

The SiS's inclusion of learning technologies (Information and Communications Technology [ICT]), links with the wider community, and explicit reference to catering for students' individual needs and preferences ensures that most major factors that support effective learning of science are considered in this project's analyses. Furthermore, the SiS reference to aspects of the NoS means that all key NoS attributes are considered, not just investigating scientifically. A more complete list of attributes is in Appendix 2.6.

2.21
Nature of science

Some primary teachers may not consider explicit teaching about the NoS appropriate for young learners, but there is adequate evidence to suggest that the youngest of primary learners can appreciate some of the attributes, while upper-primary students can grasp, to some degree, all of them (Akerson, Buck, Donnelly, Nargundi-Joshi & Weiland, 2011).

Ideas for incorporating the explicit teaching of the NoS into science teaching are straightforward and there are suggestions on how this may be accomplished at different stages in the primary school (Akerson et al., 2011). If teachers:

- use their 'imagination' to see 'the ways children engage with inquiry-based science (and then see) a future scientist or activist'[5] (Carlone, Haun-Frank & Kimmel, 2010, p. 960); or
- believe, like Logan (a teacher in Carlone, Haun-Frank & Kimmel's study), that 'across the board … every child sees themselves as a scientist unless someone tells them that they're not … '

then there is a platform for Primary Connections teachers to act on this SiS condition of representing the NoS in its different aspects.

5
As the 'tempered radical' teachers (*see* section 2.6) saw their students.

2.22
Learning technologies (ICT)

As the SiS components indicate, learning technologies need to be exploited for their learning potentialities. ICT can become the 'sixth E' and the learning cycle be titled the '6E learning model'. In this proposal by Chessin & Moore (2004), ICT (which is any use of electronic media) ties the five phases together. They provide examples of the integration of ICT across each of the 5E phases for students in the lower primary years[6].

Meeting this condition, though, may not be straightforward for primary teachers (e.g., see difficulties encountered in the research findings under 'Instructional materials' in Appendix 2.5). In another study 'using telecommunication-supported instruction' was rated the lowest (~70% of teachers reported use of this strategy) among a range of science reform teaching activities: most others were 97–100% (Marbach-Ad & McGinnis, 2008, p. 171). Reasons for this result were frustrations in ICT's procedural and logistical use. Positive experiences were also reported. Learning technologies and how they are used may be the focus of some teachers' feedback about implementing Primary Connections units.

6
More sophisticated uses of ICT within a constructivist framework of learning (*see* e.g. Degennaro, 2009) are not the focus in this study as the software was not available, and the concomitant pedagogy has not been the focus of professional development.

2.23 Assessment

Both the SiS components and Primary Connections see assessment as embedded within learning; it is linked to all phases of the 5E learning cycle. Diagnostic, formative and summative assessment all have a role but formative, or active, assessment is where teaching and learning meet, and is especially important in improving learning (Black & Wiliam, 1998; Naylor & Keogh, 2007). One of Harlen's (2009) perspectives focuses on formative assessment. Teachers' ongoing assessment of students aims to help them think about their conceptual and other learning (e.g., their use of inquiry processes), and assist them in being intentional in their learning, or metacognitive. Self and peer assessment, therefore, are also integral to learning from a constructivist perspective (Atkin, 2002; Skamp, 2012a). These and other aspects of assessment will guide some of the analyses in this project.

'Teachers who have deep understandings of the learning cycle use students' data in helping them construct the (focus) concept.'

2.3 Teacher understanding of the 5E model

This project is, in part, seeking evidence as to whether teachers are implementing the 5E model as it was intended. This would be dependent on how well teachers understand the purposes of the 5E learning cycle. It may not be assumed that relatively brief professional development about the learning cycle will necessarily lead to understanding. Many preservice teachers (n=55)* who had received instruction and read and critiqued research about the learning cycle, engaged in group and class discussions about it, participated in model 5E lessons, as well as having developed lesson plans based on the model and taught a lesson using the 5Es, still had a limited understanding of the model (Hampton, Odom & Settlage, 1996). Clearly, they found it difficult to understand. They held a range of misconceptions about it; some of these are outlined in Appendix 2.7.

Other studies[7] (reported in Cavallo & Laubach, 2001) have determined that teachers vary in their understanding of the 5E learning cycle from a 'sound understanding to misunderstanding' (p. 1036). Teacher behaviour varied in each of the phases depending upon their understanding of the model.

> Teachers who have deep understandings of the learning cycle use students' data in helping them construct the (focus) concept. These teachers question and challenge students to construct the idea without providing answers, thereby elevating the level of inquiry in the classroom. Teachers who misunderstand, misinterpret or misuse the Learning Cycle model often fail to use students' data in constructing the concept, turn questions and discussion leading to the concept into lectures, or provide answers to the investigations before students have collected data themselves (verification) (p. 1036).

* n = number

7 In a recent review of research on the impact of the learning cycle, Marek (2009, pp.147–48)) unequivocally states that teachers 'must understand the learning cycle's theoretical underpinnings to successfully' implement it with their students. 'Teaching behaviours were found to follow distinguishable patterns depending upon teachers' understanding of the learning cycle and theory base.' Marek then provides examples of various patterns of behaviour if teachers had a limited understanding of the cycle. These patterns, on the basis of related research, would result in less effective learning in science.

These findings clearly emphasise that for Primary Connections to have a meaningful impact on students' learning teachers must have an understanding of the major principles and pedagogy underpinning the 5E model. Indications of their understanding were explored by reading their comments to see if they aligned with the purposes of each phase.

2.31
Science Teaching Efficacy Belief (STEB) and teacher understanding of the 5E model

How well teachers appreciate the overall purpose of the 5E learning cycle and the purposes of each of the phases is therefore a key consideration when interpreting teachers' feedback related to their implementation of Primary Connections units.

Science Teaching Efficacy Belief (STEB) refers to teachers' 'belief in an ability to and the likelihood of affecting a situation in a desirable fashion' (Settlage, 2000, p. 45); here, that would be positively affecting students' learning in science. If a teacher's STEB increases it indicates an increase in confidence to teach science and possibly a belief that they can positively affect students' science learning. Settlage (2000) tentatively interpreted positive correlations between preservice teachers' STEB and their understanding of the learning cycle as indicating that an appreciation of the purposes of the phases of the learning cycle can lead to an increase in STEB (and, hence, greater confidence to teach science). If teachers' feedback about implementing Primary Connections units suggests an understanding of the learning cycle, then it could suggest that their 'personal science teaching efficacy' may have increased.

2.4 Teacher implementation of the 5E model

Early benchmark studies of the implementation of the 5E learning cycle established several fundamental requirements for the most effective learning of conceptual science. Thus, research found that learning was less effective if a phase was omitted and/or the phases were taught out of sequence. Furthermore, the *Explain* phase was important to 'optimum learning' and:

> explaining a concept before providing experience with materials results in little or no conceptual understanding ... exploration, which produces data, needs to be followed by discussions (as in the *Explain* phase) ...
>
> (Abraham & Renner, 1985; Renner, Abraham & Howard Birnie, 1988 cited in Marek, 2009, p. 144)

As indicated, the 5E cycle can be considered a different paradigmatic approach to teaching science. There is a range of studies that has documented the conceptual growth that occurs when teachers implement the 5E learning cycle (for a review of the research *see* Brown & Abell, 2007; Marek, 2008). However, how well teachers implement the 5E learning cycle[8] may have a differential impact on student outcomes. This means that teachers' understanding of the purposes of the phases in the learning cycle and their decisions and actions in and across these phases becomes more important.

8
This is referring to the 'fidelity' with which teachers implemented the 5E model. Fidelity refers to 'how well an intervention is implemented in comparison with the original program design during an efficacy and/or effectiveness study' (O'Donnel, 2008, p. 33). Fidelity, in this sense, cannot be determined using teacher feedback, but indications of fidelity may be able to be inferred.

Teachers' classes in Cavallo & Laubach's (2001) research were characterised as exhibiting high paradigmatic/high inquiry or low paradigmatic/low inquiry characteristics. Teachers whose classrooms were consistent with the 5E learning model were termed 'high paradigmatic', and, if inconsistent, then 'low paradigmatic. The findings related to six North American year 10 biology teachers and their 119 students. Where the science classrooms were high paradigmatic/high inquiry then more female students tended to enrol in elective senior science courses. This was attributed to the collaborative nature of learning and the encouragement of different forms of expression. Although high paradigmatic/high inquiry science classes did not influence male enrolments in senior science courses, those males and females from these classes that did enrol in senior science had more positive views of science. Furthermore, these students gave different reasons for wanting to study science in senior secondary school. These included wanting to learn more science, enjoying and liking the subject, 'science is helpful to me as a student' and 'science is fun'.

Interestingly, in this study, students who were not going to enrol in further science subjects but were from high paradigmatic/high inquiry classes had lower overall science perceptions than their counterparts in low paradigmatic/low inquiry classes. It was suggested that such students may wish to avoid the challenges expected in high paradigmatic/high inquiry classes (e.g., think autonomously about questions they cannot answer).

In summary, Cavallo & Laubach (2001, p. 1059) commented that their findings:

> coincide with … previous studies, in that students who experience a higher level of inquiry do possess more positive attitudes toward science and the science classroom. Importantly, this study extends previous work with the finding that students in high paradigmatic learning cycle classrooms have more positive attitudes (towards science) ….

These research studies have implications for primary teachers implementing the Primary Connections units. The fidelity with which teachers implement the 5E model will impact on their students' conceptual learning and may have a direct impact of some students' feelings about science as a subject[9]. Whether Primary Connections teachers are implementing the 5E model in full, and as intended, may be inferred from their feedback comments. Also, the reactions of students from high paradigmatic/high inquiry or low paradigmatic/low inquiry classes may inform interpretations of some Primary Connections teachers' feedback comments. Primary and secondary students in classes where the learning cycle model was being implemented were more highly motivated, more curious to learn about specific topics and had an overall increased excitement about learning (Barman in Marek, 2009); teachers' comments about students' affective reactions will be noted in this project.

9
Cavallo & Laubach's finding that some year 10 students reacted negatively to the pedagogy associated with the cycle may be problematic at the primary level as primary students may still be forming their views about science as a subject. This position, though, is also problematic as some studies have indicated that upper primary students may have already formed (relatively firm) attitudes towards science (*see*, e.g., Logan & Skamp, 2005).

2.5 Factors influencing teacher willingness to change pedagogical practices

2.51
Professional development and Primary Connections teachers

Most of the teachers who have provided feedback about the implementation of Primary Connections units have engaged in an introductory professional development course about the structure and educational philosophy of the program[10]. However, for these teachers, the content and duration of their professional development also includes the implementation of one or more trial units and providing detailed feedback about their implementation. This additional involvement in professional development will have varied in its depth depending upon how each teacher interacted with the Primary Connections materials and reflected upon their meaning and implementation.

In an unusual finding, Supovitz and Turner (2000) reported that during the early periods of professional development about inquiry-oriented pedagogies teachers initially experienced negative reactions, but after 40–79 hours, positive effects started to emerge. If professional development of these Primary Connections teachers embraces the implementation and feedback on the trial units, then teachers in this project may have fallen in this range. Hence, for some, if they were not already positively oriented towards the pedagogies associated with Primary Connections, their extended time involvement may have assisted in the development of a more positive orientation towards pedagogies associated with the 5E model. Periods of a year or more have been reported for teachers to change their teaching philosophy and approach towards a learning cycle mode (Barman in Marek, 2009) and this needs to be borne in mind in analysing teachers' comments. In the discussion that follows, the nature of professional development is not the major focus, although it is clearly a factor that may influence teachers' willingness to change their practice.

'Primary and secondary students in classes where the learning model was being implemented were more highly motivated, more curious to learn about specific topics and had an overall increased excitement about learning.'

2.52
Readily identifiable factors

Considerable research has investigated why pedagogical reform in science education has been slow to eventuate[11]. This reform embraces constructivist and inquiry-oriented science practices. At one level the reasons are common across numerous

10
Aspects covered in the professional development course are included in AAS (2008).

11
It has been suggested that students do not detect that teachers are using constructivist practices for at least two or more years. This may be even longer at the upper-primary level where students may be more accustomed to transmissive pedagogy (Yore, Anderson & Shymansky, 2005). As there is evidence that traditional pedagogy is changing to a more progressive pedagogy in some Australian schools (Goodrum, 2006), this time may be less. However, this proposition needs to be borne in mind when interpreting teachers' feedback comments.

studies. Many teachers perceive that sophisticated equipment is required and equipment is difficult to access, administrative support is lacking, school climate is not conducive to change, many science concepts are too abstract and difficult for primary students to understand, science is not relevant to students' lives, and there simply is not enough time to teach science (Levitt, 2001; Smith & Southerland, 2007; Carlone, Haun-Frank & Kimmel, 2010 and numerous references therein).

With specific reference to avoiding inquiry-oriented pedagogies teachers either lacked adequate science background and/or experience or confidence in using inquiry-oriented practices, which some considered to be taking too many risks with their teaching; others believed that inquiry strategies would not assist student learning and, also, that it would be difficult to oversee authentic science investigations (Sahin, Isiksal & Ertepinar, 2010; Smith & Southerland, 2007). Teachers who were recent graduates mentioned difficulties with other staff (Marbach-Ad & McGinnis, 2008), and this was also reported by experienced teachers of inquiry science (Carlone, Haun-Frank & Kimmel, 2010). In Sahin, Isiksal & Ertepinar's study, more experienced teachers and those from private schools reacted more positively towards inquiry-oriented science, perhaps due to adequate resources and technology (which also may raise their STEB). These factors may be seen as 'institutional characteristics' or 'individual teacher characteristics or propensities' (Smith & Southerland, 2007, pp. 397–98), and most of them 'unintentionally position teachers as the source of the problem' (Carlone, Haun-Frank & Kimmel, 2010, p. 942). Primary Connections teachers would experience one or more of these factors.

2.53
Teacher beliefs as a factor

Teacher beliefs, which are among the above factors, are thought by many researchers to be a pivotal consideration when seeking changes in pedagogical practices. Studies across many years have found that teachers with low STEB scores (*see* section 2.3) tend to hold beliefs inconsistent with inquiry-oriented pedagogy (Sahin, Isiksal & Ertepinar, 2010) and also devote less time to science content and processes- and inquiry-oriented behaviours such as pre- and post-activity discussions (Riggs, Enochs & Posnanski, 1998).

Levitt (2001), Marbach-Ad & McGinnis (2008) and Smith & Southerland (2007), in reviewing numerous studies, concluded that there is substantive evidence that teachers' beliefs about science, teaching science and learning science directly influence their classroom decisions and actions about teaching science.

> Theory holds that people tend to act according to their beliefs. More accurately then, as Haney et al. (2002) suggested, the beliefs that teachers hold regarding science reform ideas are truly at the core of educational change.
>
> (Marbach-Ad & McGinnis 2008, p. 162)

> In some cases, teachers' conceptions of specific subject matter and content instruction are completely incongruous with those of policy makers or reformers.
>
> (Smith & Southerland, 2007, p. 399)

Teacher beliefs, therefore, can be an impediment or a catalyst for science education reform. Whether particular teachers' beliefs will assist reform is complicated, because teachers interpret characteristics of science pedagogy in different ways. Levitt's (2001) case study research describes how teachers had different meanings for common pedagogical expressions such as hands-on activities, students as active participants, co-operative learning and what it means for science to be personally meaningful. Hence, although such features could be aligned with, for example, the Primary Connections approach to teaching and learning science, when teachers use such expressions they may not really be describing features that characterise Primary Connections.

To further complicate the interpretation of teachers' comments about their pedagogy and/or their implementation of curriculum changes, they rarely use the pedagogical terminology of science education policy documents or curriculum initiatives such as Primary Connections. In an extensive number of interviews with teachers, for example, Levitt (2001) reported that no teachers referred to 'inquiry' in their interview responses about their primary science pedagogy. This might also be anticipated in trial teacher comments about Primary Connections; for example, references may not be made to the application of a particular concept in a new context or the elicitation of students' alternative conceptions.

2.54
Teacher beliefs and the influence of context

Teachers' beliefs are influenced by their context. This can be their designed (e.g., buildings), human (e.g., students) and sociocultural (e.g., policy) environment. Depending upon how teachers engage with their context, it can partially determine how effectively they function as teachers of primary science. This has been characterised as their 'context belief about teaching science' (CBATS), which is indicative of teachers' perception of their control over their environment when teaching science. CBATS is a measure of a teacher's agreement with whether an enabling factor (e.g., science equipment, students' abilities) will assist their effective teaching of science together with whether such a factor is likely to be present in their school—the likelihood factor[12] (Lumpe, Haney & Czerniak, 2000).

In their survey of K–12, teachers (n=262) who had participated in long-term science education professional development related to US reform initiatives, Lumpe, Haney & Czerniak (2000) reported that most of the 28 categories in their CBATS measure were rated highly as enabling categories, with hands-on kits, state standards and teacher support thought to be the most likely to occur in their school, while class size, planning time, classroom environment, science equipment and funding had the largest gaps between enabling and likelihood scores. These findings about enabling and likelihood beliefs may assist interpretation of Primary Connections teachers' feedback about implementing units.

Teachers' context beliefs and their self-efficacy beliefs can be combined to describe a teacher's 'Personal Agency Belief' (PAB) pattern which can be indicative of their level of motivation to be an effective teacher of science. These patterns can vary. Significant patterns suggesting teachers would be effective teachers of science were labelled 'robust' (high context and self-efficacy belief) and tenacious (moderate context and self-efficacy belief), but professional development was urged for the latter. Patterns that were 'less functioning' (low context and/or self-efficacy belief) may hinder teachers' desire to implement different science pedagogies (Lumpe, Haney & Czerniak, 2000).

In another study reformist science teachers saw themselves as '*becoming*' science teachers, rather than statically labeling themselves as science or non-science persons or teachers (Carlone, Haun-Frank & Kimmel, 2010). If teachers of

12
These two factors accounted for 24% of the CBATS variance.

primary science perceived themselves as 'becoming' rather than static, then beliefs need not be an irresistible barrier to pedagogical change. They would, however, on the basis of the above research, need to display an appropriate PAB pattern. If a Primary Connections teacher has the desire to engage their students in more science, and, in particular, more constructivist and inquiry-oriented science, then they can draw on what similar teachers have found to be a 'critical resource' in encouraging them to persist in teaching constructivist and inquiry-oriented science. This critical resource was *to keep trying to teach in these ways*. This helped these teachers to see 'becoming science teachers' as a life-long professional process (Carlone, Haun-Frank & Kimmel, pp. 956, 961).

The above finding is also consistent with considerable evidence (*see* Levitt, 2001) that indicates teachers' beliefs and actions can interact with each other and that changes in one can result in changes in the other. This is reassuring, as Lumpe, Haney & Czerniak (2000) reported that many studies have concluded that teachers' beliefs are stable and resistant to change. In Levitt's (2001) numerous interviews (n=262) with teachers familiar with science-education reform packages, she reported that when some teachers implemented a new science program and observed the impact on students' interest and learning, their belief and commitment to the new program changed positively. This, though, took time as teachers needed to reflect on what was happening. Also, the time taken will differ for every teacher. Furthermore, it was surmised that with pedagogies such as inquiry-oriented science, deeper issues may not surface until teachers feel more at ease with the 'how-tos' and the 'whats' of the new approach. For Primary Connections this could include, for example, the 'word wall' or the 'investigation planner'.

2.55
Context as a factor: teachers not necessarily the victims of context

With reference to pedagogical reform, as suggested above, context would commonly be interpreted as the teacher's classroom interactions and, sometimes, interactions with other teachers and school climate. An even wider view of context includes school norms and expectations, interactions between the school and its community (e.g., parental views) and external policies that guide curriculum and teaching decisions, as well as how a teacher forms their identity (*see* Warren in Smith & Southerland, 2007). Using this interpretation a teacher's context also refers to how the teacher interacts with these school structures and characteristics. Teachers, therefore, need not be 'victims of context'.

Based on this extended contextual framework the beliefs and actions of two teachers familiar with inquiry-oriented science teaching were investigated (Smith & Southerland, 2007). These teachers' beliefs and decisions were not interpreted through a lens that saw them as 'victims of context', but rather that 'there is a dynamic relationship between the externally imposed and the internally constructed faces of context' (p. 400). Teachers can act on their context just as the context can act on them. Using this interactive contextual lens, Smith & Southerland contrasted two teachers' beliefs and decisions. Both were aware of the existence of national reform documents outlining science teaching policy and curriculum initiatives, but they rarely influenced these teachers' decisions. The following characterises two types of teacher:

- Teachers, if like Vicki, formed their own view of, for example, inquiry-oriented science teaching, which usually was not consistent with reform documents.

Hands-on activities, for example, do not necessarily mean that inquiry is occurring, and discussion does not necessarily mean that students' ideas are being valued. A view that Vicki believed in was that '"having fun with stuff for awhile" does not teach science concepts'. Vicki did use hands-on tasks, but only to vary activity type, not as an inquiry-oriented approach to learning—most of her hands-on tasks were followed by teacher recitation and student writing (p. 409);

- Other teachers, if like Hannah, teach in a way consistent with many of the suggested national policy reforms (e.g., using an inquiry-oriented science pedagogy) because of their fundamental beliefs about how students learn, not as a result of reading the documents. Hannah believed students 'learn science by experiencing it: through asking questions, solving problems, investigating, making mistakes, and connecting science concepts to real life', and they need to understand 'basic processes: how to explore, how to discover, how to answer questions, how to experiment with things, how to observe, how to use and apply information. As part of science, these things are also important for them to learn' (p. 410). Her decisions were based on her 'passion' about what she thought students should be taught in science. Her selection of content was still guided by her state curriculum, but also 'determined by level of interest to [her] and what [she] think[s] would be interesting and applicable to [her] students' (p. 413).

These teachers, if typical, suggest that practitioners modify reforms (like Primary Connections) in a range of ways, including ignoring them. Their own identities and beliefs interact with reforms, such as calls for constructivist and inquiry-oriented teaching, and policies like externally imposed testing. In Smith & Southerland's (2007) study the teachers 'ultimately (chose) to remain true to their personal theories of appropriate practice, both despite and because of the external pressures imposed by the tools of reform' (p. 417).

How teachers interact with recommended changes in science pedagogy directly relates to the implementation of Primary Connections. This initiative hopes teachers will appreciate the learning model that underpins it (the enhanced 5E cycle). As outlined (*see* earlier in this section, viz., 'Professional development and Primary Connections teachers'), teachers who have trialled Primary Connections units have encountered professional development about the initiative, its learning model and associated strategies. The extent to which they have experienced:

> scaffolded opportunities over time, with other teachers who are focusing on the same issues, and with the specific content they are teaching … [and have] directly wrestle[d] with the messages of [Primary Connections material] and [have] work[ed] through the implications of the [Primary Connections aims, purposes and pedagogy] for their own teaching practices
>
> (Smith & Southerland, p. 417)

will probably influence how much their teaching practice aligns with the teaching and learning intentions of Primary Connections. The additional task of implementing trial Primary Connections units and then being encouraged to provide directed feedback about lessons labelled with each of the five phases of the learning cycle model, may have been influential for some. Even so, it needs to be borne in mind that Smith & Southerland concluded:

> It is important to recognise that teachers *tend* to perceive [curriculum initiatives and resources] only in terms of content [and activities]; they do *not* look to these [initiatives and resources] for description of how that content should be taught. (p. 418, parentheses and emphases added)

2.56
Teacher beliefs, contexts and global Discourses

As indicated above, (*see* 'Context as a factor'), teacher beliefs can interact with a teacher's context in different ways. This context can include awareness and familiarity with key science education policies and curriculum initiatives. These reforms usually contrast with 'Traditional Schooling Discourse' ('Discourse' with a capital 'D'), where Discourses are 'taken for granted practices and meanings' that 'authorise or sanction allowable practices and meanings' (Carlone, Haun-Frank & Kimmel, 2010, p. 944). Traditional Schooling Discourse (TSD) refers to the 'teacher as authority, students as recipients of knowledge, and science as a body of knowledge … schooling is conceptualised as a form of exchange of knowledge (from teachers to students) for control (of students by teachers)'. Primary Connections advances a more progressive global Discourse consistent with the purposes, teacher roles and conditions for effective science education outlined in earlier sections and the various appendices.

In their most comprehensive study Carlone, Haun-Frank & Kimmel (2010) followed thirteen teachers who were selected because their beliefs and classroom actions aligned with a more progressive Discourse that, for example, gave more agency to students and required students to be more accountable to each other and the standards of science as a discipline. The last mentioned would include investigative, communication and epistemic practices accepted within a community of science practice. In this in-depth research, these teachers, while mentioning many of the barriers to embracing reform (*see* earlier, in section 2.5), constantly alluded to 'Institutional meanings' (I-meanings) of the curriculum. In the case of primary schools these would be what gets taught (where does science fit, if at all?), and for science, when and how it is taught. In Australia, NAPLAN (National Assessment Program—Literacy and Numeracy [NAPLAN] testing process [ACARA, 2010]), and its curriculum and pedagogical consequences, could be interpreted as impacting on a progressive global (science education) Discourse by privileging literacy and numeracy outcomes (and hence, indirectly, supporting a TSD). This TSD would influence teachers' science education beliefs and practice; for example, lack of time for inquiry-oriented science might be mentioned by teachers, but the underlying reason would be related to institutional practices and structures. As Carlone, Haun-Frank & Kimmel (2010, p. 949) concluded, these I-meanings 'sanctioned teachers' roles by defining what was allowable and legitimate'.

However, these thirteen teachers, similar to Hannah (*see* earlier, in section 2.55), were passionate about teaching science to young learners. They saw teaching science as a 'moral responsibility to the future of their students, science, and society' and their conscience would not let them do otherwise (Carlone, Haun-Frank & Kimmel, 2010, p. 951). They did (and could) not ignore the TSD, while still practising, to different degrees, an alternative science education Discourse. They were 'tempered radicals' who worked on a 'fault line'. They saw themselves in the process of 'becoming': 'becoming science people, teachers and reformers' (p. 955). They also saw their students in the same way—student learning was about 'becoming': becoming science investigators, thinkers, questioners and also scientists.

Primary Connections teachers, to be effective implementers of constructivist and inquiry-oriented science, will to some extent have to be tempered radicals. In some

Australian schools pedagogical practices may be changing (Goodrum, 2006), and I-meanings could be changing or being diluted, but they will still be present. These I-meanings are one lens through which feedback from trial Primary Connections teachers can be interpreted.

2.57
Tempered radicals and other pedagogical change issues

Tempered radical teachers (*see* above) made decisions and took actions in their science teaching for reasons that would differ from teachers who did not see primary science teaching as a moral imperative. Two types of actions tempered radicals have taken that are relevant to this study are outlined below.

Integration of science with other subjects

Some of these tempered radicals addressed I-meanings and more progressive science education global Discourses by connecting various subjects, including mathematics and English (reading, writing, listening, talking), with science. Science became the vehicle for these other areas, helping to make them more meaningful, as these teachers believed science is everywhere and fully integrated with students' lives. In other words, integration of subject areas was natural 'because of the connected nature of science' (Carlone, Haun-Frank & Kimmel, 2010, p. 952); from this perspective integration is not an excuse used by teachers to avoid inquiry and constructivist science, or even to teach less science, but is an indicator of how interest in science and science learning can be enhanced. When Primary Connections teachers refer to how they have integrated science unit content with other curriculum areas, their actions could be seen in this light. The Primary Connections approach and units assist in this development not only with their overt generic literacy 'connections' but also with their references to numeracy and other subject areas. As Yore, Anderson & Shymansky (2005, p. 67) comment:

> It is literacy in the fundamental sense that defines the essential nature of language in science, that resonates with generalist elementary teachers, and that illustrates potential connections of science to the priority curriculum domain in elementary classrooms—the language arts.

Meeting SiS conditions for supporting learning of science

In these tempered radicals' stories (Carlone, Haun-Frank & Kimmel, 2010), there were many examples of their alignment with a progressive global Discourse, while still acknowledging the presence of the TSD. Their view of science 'as everywhere' helped them make science accessible to students and, hence, meaningful. Their appreciation of inquiry-oriented science meant that their students had a voice and that assessment tended to be more authentic. These are all SiS conditions to support effective science learning.

2.6 A Primary Connections case study

Two Queensland mid-career male primary teachers who had participated in workshops associated with the Primary Connections professional learning resource (AAS, 2005, 2007) were tracked for six months as they implemented Primary

Connections in their classrooms (Fittell, 2010a, b). Interview, observation and documentation data indicated that over time these teachers started to appreciate that less 'teacher talk' and direction (than was their usual practice) allowed students to be more autonomous in their learning. Additional opportunities were provided, after scaffolding, for more open-ended activities (e.g., to explore the pushing and pulling aspects of a toy) for students to try out ideas and share their thoughts between themselves. Independent and group investigations became more common. The teachers linked these pedagogical changes to increased student engagement and enjoyment, and improved learning outcomes. Their beliefs about how students learn science changed because they witnessed these changes. As the teachers whose comments are the data for this current study usually had similar or longer experiences to those described in Fittell's research, then comparisons may be made with his findings.

2.7 Summary: analysing and interpreting teacher feedback

Primary Connections revolves around an enhanced 5E learning cycle. It may be considered a science education reform initiative that is encouraging teachers to embrace constructivist and inquiry-oriented pedagogies. In Primary Connections, there is a balance between personal and socio-cultural constructivist emphases and, hence, teacher and learner roles reflect this duality. Primary Connections also aims to develop a supportive environment for students (and teachers) to learn and teach science. Expectations of what learners and teachers would be doing in Primary Connections classrooms are encapsulated in a range of checklists that are described and placed in context in sections 2.3 and 2.4.

Many teachers in this project have trialled one or more Primary Connections units and submitted extensive feedback on the strengths and weaknesses of the overall sequence within a unit and the tasks within each phase of the 5E model. They also added comments about the strengths and weaknesses of other aspects of the unit(s), such as their implementation of the 'word wall' and the 'investigation planner'.

As there is research evidence connecting teachers' understanding of the learning cycle (and how well they implement it) with students' science conceptual outcomes and interest in science, then one facet of analysing teachers' feedback comments would be to see if they show an understanding of the 5E model and what it means to implement it (*see* sections 2.5 and 2.6).

When teachers reflect on their implementation of Primary Connections units, the strengths and weaknesses they identify will also illuminate in some way their perceptions of their teaching context, as well as their beliefs about science, science teaching and science learning. Reading their comments through the various lens of the studies overviewed in sections 2.6 and 2.7 will assist in discerning what factors may be influencing their comments, and also provide a wider landscape upon which to draw when seeking to understand the reasoning underpinning their thinking.

'Primary Connections also aims to develop a supportive environment for students (and teachers) to learn and teach science.'

Chapter 3

Research methods

3.1 Research purpose and specific research questions

The broad aims of this research are encapsulated in the following general research questions:

- What understandings and insights about learning and teaching of science are embedded in teacher feedback about the implementation of trial units of Primary Connections?
- What are the implications for the development of curriculum support materials from these insights?
- What are the implications for the future professional development of Primary Connections teachers from these insights?

3.12 Specific research questions

In what ways does teacher feedback about the implementation of trial Primary Connections units imply:

i teachers' understanding, and practice, of the 5E learning cycle and associated constructivist and inquiry-oriented pedagogies (e.g., purposes, teacher and student roles)?

ii if characteristics and conditions for effective science practice were present (e.g., reference to meaningful conceptual learning, interest and engagement of students development of science inquiry skills, appropriate use of ICT)?

iii whether other factors (e.g., teachers' beliefs) emerged from the data that were enabling (or obstructing) effective constructivist and inquiry-oriented science practice?

How do inferences from teacher feedback vary in relation to (i) and (ii):

- across different levels of Primary Connections units within the same content strand?
- across different content strands of Primary Connections units?

Responding to these research questions also will provide some insights into the fidelity of implementation of Primary Connections' aims and purposes. These inferential insights will have limitations but could provide pointers for further investigation into the effective implementation of primary science based on the pedagogical principles underpinning Primary Connections.

3.2 Conceptual framework

The research design is set within the parameters of the aims, purposes and underlying rationale of the Primary Connections program, especially its intended implementation of an enhanced 5E learning cycle, and research and professional literature that has identified attributes of effective primary science practice. In responding to the above research questions, analysis and interpretation of teacher feedback from trial Primary Connections units will be guided by findings from this literature.

The pedagogical principles relevant to this research are those that underpin Primary Connections. These include its use of the 5E learning cycle as a constructivist learning model to plan and implement science at the primary level. This pedagogical model has been enhanced by Primary Connections to incorporate strong connections between science and literacy, an emphasis on inquiry-oriented science with investigating scientifically as a focus, assessment that is embedded across the 5E phases, as well as cooperative learning (AAS, 2008a). The 5E learning cycle and its embedded enhancements were the focus when the teacher feedback data was analysed. Indigenous perspectives are also a focus of Primary Connections but not in this project.

Chapter 2 is a literature review that identifies major research findings relevant to responding to this project's research questions. Integrated within this review are comments which link the literature to how the Primary Connections teacher feedback data were analysed and interpreted. The literature review includes the following sections:

- the 5E learning cycle and personal and socio-constructivist emphases within it;
- the characterisation and components of effective learning of science;
- teachers' understanding and implementation of the learning cycle; and
- factors influencing teachers' willingness to change pedagogical practices.

This integrated review of the literature provided a range of lenses through which the teachers' feedback was read. This provided insights into the teachers' feedback that otherwise could have been overlooked.

3.3 Research design and methods

The overall approach used in this project was mainly a qualitative content analysis of the comments that teachers made in their feedback about their trialling of Primary Connections units. Here 'meaning' will be derived from what is explicit in the words used or 'what can be implied from their use from the range of alternatives that may have been employed' (Miller & Brewer, 2003, p. 43). Where feasible, and appropriate, frequency counts or estimates of frequency related to various 'meanings' have been included. The researcher used a knowledge of the Primary Connections project and its units and related research (*see* Chapter 2) to 'read into' the teachers' responses and likely interpretations of what teachers may be suggesting about their understanding and implementation of various pedagogies which are the focus of this project[13] (*see* 'research questions' [section 3.12] and 'conceptual framework' [section 3.2]).

13
In this sense, this project is qualitative interpretive research in that the researcher is making a personal assessment of what the teachers' comments are suggesting (Creswell, 2008).

3.31 Sample

The sample was predetermined by the availability of written teacher feedback about the implementation of trial PC units. This feedback was provided to the Primary Connections team over the six years and three months of the trials (2005–2012). A selection of teacher feedback from sixteen units was selected. Four units were selected from each of the four content strands of 'Life and living', 'Energy and change', 'Natural and processed materials' and 'Earth and beyond'. Within each strand, a unit was selected from each stage (Early Stage 1 [ES1], Stage 1 [S1], Stage 2 [S2] and Stage 3 [S3]) and, where possible, units that were linked, for example, *On the move* ES1 and *Smooth moves* S1 (*see* Table 3.1).

Table 3.1 Primary Connections units analysed in this report

Stage	Trial Unit Title (Final Title)
Strand	**Natural and Processed Materials**
ES1	*What's it made of? (What's it made of?)*
S1	*Material matters (Spot the difference)*
S2	*All sorts of stuff (Material world)*
S3	*Change detectives (Change detectives)*
Strand	**Life and Living**
ES1	*Staying alive (Staying alive)*
S1	*Schoolyard zoo (Schoolyard safari)*
S2	*Plants in action (Plants in action)*
S3	*Marvellous micro-organisms (Marvellous micro-organisms)*
Strand	**Energy and Change**
ES1	*On the move (On the move)*
S1	*Push-pull (Push-pull)*
S2	*Smooth moves (Smooth moves)*
S3	*Electric circuits (It's electrifying)*
Strand	**Earth and Beyond**
ES1	*Weather in my world (Weather in my world)*
S1	*Water works (Water works)*
S2	*Spinning in space (Spinning in space)*
S3	*Earth's place in space (Earth's place in space)*

3.32 Data

Documents are the main (qualitative and unobtrusive) data source. These were the detailed written teacher feedback notes (based on a supplied pro forma[14]) from the implementation of numerous Primary Connections trial units. Further feedback

14 Teachers who trial Primary Connections units are asked to provide feedback about the strengths and weaknesses of the overall unit, its various components (e.g., resource sheets, word walls, investigation planners), each of the lessons in the various 5E phases, together with any other comments to improve future implementation of the units.

from selected teachers was obtained from a two-tier multiple-choice test that determined teachers' understanding of the purposes of the *Explore*, *Explain* and *Elaborate* phases of the 5E learning cycle (Odom & Settlage, 1996). Approximately 60 tests were distributed by email and 11 returned (response rate about 20%.

The summaries of teachers' feedback responses for each of the 16 units comprised approximately 10–20 pages of typed notes. This feedback documented teachers' views about the strengths and weaknesses of the overall unit, each of the lessons in the various 5E phases, its various components (e.g., resource sheets, word walls, investigation planners), together with any other comments to improve future implementation of the units. Individual teacher feedback about any one of these areas ranged from a few words to many sentences. For the *Engage*[15], *Explain* and *Evaluate* phases there was always one lesson, while the *Explore* phase had between two and four lessons (mean of 2.8 lessons/unit across the 16 units) while the *Elaborate* phase had between one and three lessons (mean of 1.6 lessons). Each unit had feedback on between five (*Weather in my world*) and 11 (*Water works*) lessons (mean 7.6 lessons). Table 3.2 shows that the total number of teacher responses for each of the 5E phases varied between 101 (*Evaluate*) and 196 (*Engage*). Using *School Zoo* as an example, it can be seen from Table 3.3 that teachers made 169 comments. On this basis, the estimate of the number of responses (for 16 units) that were analysed was between 2500–3000.

15
Weather in my world was an exception in that the *Engage* phase comprised two lessons.

3.33
Data analysis

The teacher feedback data were manually analysed. This process enabled the researcher to have a hands-on feel for the data and close inspection of it to ensure that nuances within the teachers' responses were not overlooked. Both deductive and inductive analytical processes were used.

The deductive analyses used three checklists. These were the purposes of each phase as described by Primary Connections (AAS, 2008a); the 5E SiS components which were found to support the effective learning of science (Tytler, 2003), and Harlen's (2009) descriptors of teacher and student roles associated with science teaching from a constructivist, inquiry, language/talk and formative assessment perspective. These are in appendices 2.1, 2.3 and 2.5. If teacher feedback comments explicitly referred to items on these checklists, they were coded accordingly; where appropriate, it was noted if other teacher comments implied the presence of these checklist items. Teacher comments that appeared to disconfirm the purposes, components or roles in these checklists were also coded. Frequency counts were made of the comments associated with the 5E purposes, while 'estimates of probability/possibility' were determined for the components and roles on the other two checklists.

If, when reading the teachers' comments using the above deductive coding, other teacher remarks suggested emerging issues of interest related to the research questions, then they were categorised under a range of headings, depending on the content of the teachers' comments as in inductive analysis of qualitative data (Creswell, 2008). As the data were analysed, if particular teachers' responses suggested an exemplary or an explicit disconfirming instance of addressing the purposes, components and roles, then they were highlighted. 'Track change comments' were used to code all relevant teacher comments and, hence, isolate feedback segments that related to a deductive code or an inductive issue or category; this process addressed the confirmability of the findings, as an audit trail could be followed.

Table 3.2: Number[*] of teachers who commented on each phase in the 5E model[**]

Unit	Engage	Explore	Explain	Elaborate	Evaluate
Weather in my world ES1	12	11	8	7	3
Water works S1	13	16	10	11	11
Spinning in space S2	16	19	14	14	6
Earth's place in space S3	14	13	11	14	13
What's it made of ES1	12	9	7	12	4
Material matters S1	12	7	8	8	5
All sorts of stuff S2	18	19	12	10	8
Change detectives S3	9	9	6	8	4
On the move ES1	9	9	7	8	6
Push-pull S1	8	7	7	6	7
Smooth moves S2	9	9	7	8	6
Electric circuits S3	16	16	14	11	9
Staying alive	8	9	5	8	3
Schoolyard zoo	12	12	9	5	5
Plants in action	10	12	8	9	7
Marvellous micro-organisms	18	15	10	16	4
Total	**196**	**192**	**143**	**155**	**101**

* The variation in totals is because some phases have more lessons than others.

** Many of these teachers also made comments about the overall unit and specific strategies, such as use of Resource sheets (*see* example in Table 3.3). These were also used to ascertain teacher input about each of the 5E phases.

Table 3.3: Number of teacher comments within a typical unit (*Schoolyard zoo* S1)

Unit Component	Number of comments
General comments	14
Specific strategies and focuses	27
Engage Lesson 1	24
Explore Lesson 2	25
Explore Lesson 3	16
Explore Lesson 4	19
Explain Lesson 5	13
Elaborate Lesson 7	6
Evaluate Lesson 8	5
Resource sheets	20
Total	**169**

16
Yore, Anderson & Shymansky's (2005, p. 86) note of caution in gathering evidence about reform efforts will be borne in mind as assertions are made. This is that 'many reforms are simply unrealistic in their expectations, looking for immediate gains in student achievement'. The literature review (Chapter 2) draws attention to related issues.

As each unit's analysis was completed an interpretive report was prepared that drew inferences as to whether, how and to what extent the purposes, conditions and roles had been identified[16]. Any emerging issues were listed separately. This process meant that the feedback comments were read on more than one occasion, and at times searched for particular terms/ideas. Extracts from the teachers' comments were added to support the naming of emerging categories. Relevant findings from the literature were integrated into the analyses.

In the reporting of the analyses, a series of codes were used to identify the location of teachers' extracts and other data. These are outlined in Table 3.4 with explanatory comments.

Table 3.4 Coding used in reporting extracts from teacher feedback

Code	Meaning
TXX (e.g., T1)	Teacher number as itemised in teacher feedback summaries (e.g., T1 = Teacher 1; TUK = teacher number not identified); Ts = Teachers)
TG	Comment made by a teacher as 'General' feedback about the unit
LXX (e.g., L2)	Lesson number within a unit (e.g., L2 + Lesson 2)
Eng	*Engage* phase
Elab	*Elaborate* phase
Eval	*Evaluate* phase
ES1, S1, S2, S3	Stage (e.g., ES1 = Early Stage 1)
CD etc.	*Change detectives*; each unit will be referred to by its initials, except for the units listed below.
WM	*What's it made of?*
MMat	*Material matters*
ASS	*All sorts of stuff*
PA	*Plants in action*
OTM	*On the move*
WW	*Weather in my world*
Ww	*Water works*
SS	*Spinning in space*
EP	*Earth's place in space*

3.4 Limitations of the research

Teacher feedback sought perceptions of the strengths and weaknesses of the Primary Connections units and the various components as a consequence of implementing them. The feedback varies in its detail and is incomplete in that teachers decided how much detail to include and no further guidance was provided as to what they could include. Furthermore, although supporting extracts from the teachers' comments were related to particular inferences about teachers' understanding, and practice, of the 5E learning cycle and associated constructivist and inquiry-oriented pedagogies, teachers were not directly asked to comment on these features. This needs to be borne in mind in reading the inferences from the data.

Also, this report is based on teacher perceptions and self-reports of what happened in their classrooms. In that sense, it will be influenced by teachers' existing beliefs about the science and how it is taught, as well as related matters (*see* Chapter 11). Teachers volunteered to provide feedback as a condition of receiving trial Primary Connections units, and reimbursement, for the resources needed to teach the units. Motivations will have varied among these volunteers and, hence, would impact on the nature and quantity of feedback.

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'… the influence of Primary Connections has produced teaching and learning environments that fulfill many criteria associated with high-quality science learning.'

Chapter 4

Implementation of the 5E model: teacher-feedback analysis and findings

Introduction

From the teacher feedback about implementation of specific trial Primary Connections units inferences can be drawn about teachers' thinking related to various facets of the Primary Connections approach to the teaching and learning of primary science. In this chapter the focus is on teachers' comments that are relevant to the overall unit and, by implication, the 5E model.

After implementing a Primary Connections unit, teachers provided feedback about the 'strengths' and 'weaknesses' of the overall unit. These comments are the main data considered in this chapter, but if teachers made comments in any other sections of their feedback that related to the overall 5E model, then they have been included in the data. It is assumed that the teachers' feedback provides insights into what they thought were the most important aspects on which to comment.

4.1 Overall responses to implementing Primary Connections units

When teachers commented on the overall implementation of these units[17], by far the most reported response was that they captured both the teachers' (n=47 [responses]; 45% [of responses]) and the students' (46; 44%) interests. The positive impact on student learning (n=20; 20%) and that teachers and students appreciated the presence of investigations (involving fair testing) and interesting observations (n=11; 10%) were the only other responses mentioned by at least 10% of teachers[18]. Relatively fewer teachers identified weaknesses. Two related limitations were reported by 10% or more of teachers, namely that the length of the units (n=22; 29%) and specific lessons (n=10; 13%) was too long and/or had too much content[19]. These data suggest that the overall content, sequence and selection of activities have engaged both teachers and students. Further, although not directly asked about, uppermost in several teachers' minds were the positive impact on student learning and the emphasis on an investigative approach.

17
Appendices 4.1 and 4.2A and 4.2B provide the reported strengths and weaknesses of implementing 16 Primary Connections units, together with summaries of the identified categories across all these units. Findings reported here are from these tables.

18
Responses referred to by 5% or more were that the units: are hands-on/practical (n=8 responses); have strong literacy links and cross-curriculum potential (n=7); have a suitable length/pace/extent of content (n=6) and show good progression (n=5).

19
Responses referred to by 5% or more were that the units: lacked cohesive/coherent concept/ideas development (n=5); concepts were too complex/abstract and did not capture the teachers' interest (both n=4).

4.2 Positive teacher feedback about the 5E model

Teachers' thoughts about the 5E model surfaced in a range of ways within the feedback responses. Most of the following derives from comments that teachers made about various aspects of implementing the unit rather than the 5E model per se[20]. In most instances it may be implied that the teachers are referring to the overall structure of the lesson sequence, that is the 5E model. Many enabling features of Primary Connections were identified, as well as potential areas for further professional development. These are outlined below.

20
For most of the analysed trial units (13/16) teachers were asked to comment on the strengths and weaknesses of the '5E model'. For this feedback item responses were provided in three of 16 units (namely, SD, SM and PA). This may mean that most teachers did not hold any views about the 5E model or that they simply accepted it. It may also mean that they did not engage with the model which underpins the structure and sequence of lessons in the Primary Connections units (although this seems unlikely for most respondents in light of other comments elsewhere in their feedback)

4.21
Positive impact of the 5E model

The long-term intention of Primary Connections is that teachers will see the value of the 5E model as an effective way to facilitate student learning in science, or as two teachers expressed it: Primary Connections is a 'good logical model that helps students progress in their knowledge and understanding in a very structured manner' (T11G SM S2) and 'I thought the details, structure of the unit & the 5E's model [made] an excellent resource and method' (T11G WW ES1). However, it was more powerfully exemplified when some teachers referred to students taking responsibility for their own learning:

> I have really enjoyed teaching this unit. The best aspect was that it provided hands-on activities for the students to engage with in a meaningful way, finding out answers by testing possibilities themselves *provided a real sense of ownership of their learning* (T22G ASS S2 [italics added]).

All three comments are consistent with several research findings as outlined in Chapter 2 (e.g., Fittell, 2010a, b).

Primary Connections is a 'good logical model that helps students progress in their knowledge and understanding in a very structured manner.'

4.22
A basis for autonomous teacher planning now and in the future

Over time, it is hoped that teachers will base their own science planning on the 5E structure. There were some teachers who indicated that they had made this decision: 'I love this (approach) and use it as the basis of all my planning' (T4G SM S2, parentheses added) and: 'I have learnt so much, but more importantly, increased in confidence to do a unit by myself' (T2G SM S2).[21]. Some teachers prefer even greater autonomy, while appreciating the value of the 5E approach, as in the following comment: 'I ... feel a unit developed by someone else doesn't work as well because you don't fully know where it is heading. I can understand why it's done and certainly I am completing more science this year' (T15G WW). Most primary teachers would align with the former two teachers, while some will need even more support, perhaps from more

21
Interestingly, these two comments relate to the SM unit which caused considerable difficulty for some teachers (*see* Appendices 4.1 and 4.2B and section 7.7).

experienced users of the model as this teacher opined: 'I would have liked to have had more support from people confident with the 5Es model when writing my own unit' (3G PP S1).

Lloyd (2007) reported her progress towards autonomous planning using the 5E model after implementing three units. Such a journey can take considerable time (Fittell 2010a; Barman in Marek 2009) as teachers may need to alter long-practised beliefs and approaches. An example is how some teachers appreciated that the 5E model requires a move away from the perception that science teaching is effective if it is 'hands-on' and 'fun'. These two features are important, but other attributes are needed if students are to focus their learning on key conceptual ideas and science inquiry skills. These other attributes include intentional student talk about science ideas and processes, and teacher scaffolding of discussion towards central ideas and science inquiry skills. As two teachers expressed it:

> Teacher and students spent too much time playing with the toys, needed to spend more time looking at the 'science' within the activity!' (T10 OTM *Explore* L4 [about 'Toys that move'])
>
> Good mixture of discussion (sitting still) and moving (observing, walking, purposeful play, role-play—better balance throughout unit and most importantly, within L4 (4G OTM S1) [Lesson 4 was an *Explore* lesson in the final version of this unit.]

The trial units were, of course, not 'perfect', and various issues were raised by teachers. Although rare, the following indicated that there were some teachers giving serious thought to the purpose of each of the 5E phases. This teacher questioned some lessons' consistency with the 5Es, illustrating their reflective analysis of what was occurring as they implemented the 5E model:

> I'm not sure about the sequence of the lessons. Students were enthused after L1 and then spent L2 reading and L3 observing when they really wanted to make things happen. Aren't these 2 lessons explaining rather than exploring? Couldn't they experiment to light up a globe and then look at the cross section diagram to explain why you had to wire it a particular way to work? (T6G EC S3)[22]

It is this level of reflection that Primary Connections would hope to engender in teachers of primary science.

4.23
Self-reported influence on teacher pedagogy

As already suggested, teaching using the Primary Connections framework may change the way teachers think about teaching science:

> This unit (*On the move*) was easier/less open/more directed ?! than Term 1 with *Weather (in my world)*. I think the new weather ideas we worked on … will make that unit easier to follow. *But, it may be that I am getting more comfortable with the whole idea of teaching science this way* (8G OTM S1, italics and parentheses added).

These thoughts can also be identified in: '(The 5E model) works well—(but) still worried about collecting wrong responses in the *Engage* phase' (5G SM S2).

These changes can even happen with teachers who perceive their science background is non-existent: 'Team teaching is difficult when the teacher you are working with has no science background. I think she is now a (Primary Connections)

22
This is of interest, as in the CD unit one of the *Explore* lessons actually was an *Explain* lesson. In that unit no teachers commented on this discrepancy.

convert and sent me an email thanking me, so something must have worked' (T1 OM S1 *Eng* parentheses added).

'Love the way each lesson builds on previous knowledge and reinforces learning.'

4.24
Focus on a key idea, central concept or understanding

A major feature of the 5E scheme is that it usually focuses on one key idea or central concept or understanding (Bybee, 2002). This was sometimes appreciated by teachers: 'Wonderful to be able to work in depth with just the movement of earth and moon and not spread thinly over all planets' (T15G SS S2). In the same unit another teacher realised that units (*Spinning in space*) were meant to focus on a key idea, but could not identify it: 'Hard to identify central idea; used "my sky" as a central idea' (T21 SS S2 *Eng*). In general support of this principle of focusing on a key idea some teachers expressed an appreciation of the cohesiveness of the 5E sequence. In the *Spinning in space* unit (as with the above teachers) a teacher said: 'Love the way each lesson builds on previous knowledge and reinforces learning' (T2G SS S2), while in another unit: 'Continuity and flow of lessons was good' (T21G ASS S2)[23].

Not all teachers appreciated this central tenet of the 5E model (i.e., a focus on a key concept or understanding); for example the following teacher suggests that in the *Spinning in space* unit it was the 'topic' that was seen as an obstacle: 'The topic was limiting as (it was) difficult to keep children focused on Earth, sun and moon and not on (the) broader topic of space' (T11G SS, parentheses added). The challenge here is for teachers to appreciate how a variety of different *content* could be related to a single central idea. Harlen (1985) details the important relationship between concepts, content and activities in implementing effective science education, and it underpins aspects of the 5E model.

23
This view was contested by another SS unit teacher who critiqued this aspect of the 5E sequence. This teacher (T4G SS) felt the unit 'lacked cohesiveness'. Interestingly, this teacher, along with another (T11 SS), considered insufficient interest was engendered (due to the focus on one key idea and that it was 'too difficult and abstract') with 'wonder and awe' not present (T4G SS). In other words, these teachers wanted the unit to have wider scope than a focus on simply the movement of the sun, earth and moon. This critique may have been related to the content of the unit, namely 'Space', which has traditionally been taught from a very wide and descriptive perspective, e.g., the planets, rather than also including an explanatory aspect as in the SS unit (*also see* section 4.61 and Skamp [2012d]).

4.25
Growth in use of Science Inquiry Skills (SIS)

There were comments that suggested some middle and upper primary students were becoming more proficient in their autonomous use of SIS. Apart from the earlier reference to students taking responsibility for their own learning (section 4.31), other typical examples included: 'Children designed their own fair test using procedure from L2 as [a] guide. Came up with similar to Resource Sheet 2. Was great assessment of knowledge of fair testing and procedure genre' (T4 MM S3 L3), and:

> After we had finished the *Schoolyard zoo* unit we happened to walk past a spider in a web. We stopped to observe—the children focused intently, observing it and commenting on its movements. They were really concentrating. I don't think they would have been quite so absorbed if we hadn't done the unit. (T2G SZ S1)

However, teachers did refer to students having to be explicitly guided in the learning of new science inquiry processes and skills, as in: 'We didn't do this very well. The children haven't had much science in earlier grades. They'll get better' (T10 PA ES1 *Elab).* This can also happen in upper primary years (and emphasises the value of Primary Connections units in the earlier years):

> Many children had not done an investigation in this manner before—I need more time to discuss how this process works and why we must follow it. This is a problem when children are new to Primary Connections (as mine are this year) and don't know the background taught in earlier modules. (T10 SM S2 *Elab*)

4.26
The value of extended and sequential learning across two Primary Connections units

As implied by the above, teachers and students who complete more than one Primary Connections unit may show evidence of SIS development. This was reported by some teachers who had taught several Primary Connections units. Conceptual growth was also mentioned.

Development of key concepts

Some teachers referred to the value of their students completing two consecutive units. In the 'Energy and change' strand two teachers who had taught *Smooth moves* commented on the value of completing two sequential units: 'Two students mentioned the *Push-pull* unit I did with them two years ago' (T1 SM L2 *Exp*), and 'The children loved these activities and particularly enjoyed the challenge of moving the ball bearing without touching it. These children did *Push-pull* previously so they were using terms such as push, pull and force regularly' (T6 SM S2 *Eng*).

Examples from the 'Earth and beyond' strand supported these teachers. One *Earth's place in space* S3 teacher said their students: 'also had a good knowledge of terminology, orbit/rotate' (from formerly completing the *Spinning in space* S2 unit) (T11 EP S3 *Eng*). Another, though, indicated that teachers using sequential units may need to adapt the later unit. This *Earth's place in space* teacher said: 'Also was based very closely on *Spinning in space* (S2 unit)[24] which is [a] connection, but students were looking to be extended more' (11G EP S3 *Eng*).

Development of SIS

As with conceptual understandings, repeated use of Primary Connections also can improve students' SIS:

> Of the few students that I had last year and again this year (I have a composite class) their bookwork was definitely the best and understood most about recording observations—building on top of skills is obviously the best practise. (T9G CD S3)

Other teachers (like the SM teacher above) believed that some of the SIS processes were new to their students and will improve with practice:

> Children had difficulty identifying variables even after using planning Chart—I think this may have confused them. Need to do many, many investigations before children will be able to work through this process with confidence and understanding. (T12 PA S2 *Elab*)

24
There is a similarity between the two units in that they both refer to the rotation of the earth, but the S3 unit does expect much more of students with reference to testing different 'models' of earth, sun and moon movements to explain phenomena such as day and night.

4.3 Feedback on the problems using the 5E model

As would be anticipated, not all teachers' comments indicated that the bases of the 5E model were understood or implemented. Evidence for the following is inferential and it needs to be remembered that the teachers' feedback comments did not directly seek responses about specific aspects of the 5E model. Hence, there may be other reasons for some of the following interpretations.

4.31 Lack of implementation of one or more of the five phases

For the most effective learning to occur teachers need to engage students in each of the five phases (Marek, 2009). There were several instances where teachers omitted a component of a phase or a complete phase or phases. Components of a phase need not be significant, provided teachers have a sense of what the overall sequence is aiming to achieve. In a limited minority of cases teachers completed the *Engage* and *Explore* phases but reported their omission of *Explain* and later phases; at other times the *Evaluate* phase was probably overlooked. The reasons for omitting phases were sometimes provided as being time-based[25]. Examples from about 20 identified responses (from six different units[26])[27] include: 'I didn't complete any more of the following lessons from Lesson 6 (i.e., the *Explain* and later phases were omitted) (T9G WW ES1); 'After getting materials ready for mystery balloon, did not have time or energy to collect things needed for this lesson' (T3 MMat S1 *Elab* L7); 'Didn't do this as too similar to what we did in Lesson 4 (an *Explore* lesson), and having already done it in Lesson 1 (the *Engage* lesson) we needed something different' (T4 SA ES1 *Eval*); 'Have taught up to L6 (i.e., omitted *Evaluate* lesson). Children more interested in latter stages of unit' (6G MM S3); 'Opted not to do (*Explain*) lesson as bread issue is becoming monotonous, class wanted to grow moulds' (T6 MM S3 *Explain*) and:

> Sorry I did not do this (*Explain* phase) as requested. I just knew the students hadn't got the understandings or interest to do this as intended. I squeezed in extra lessons as best I could, but still couldn't come at this one. (T3 SM S2 *Explain*)

These reported omissions indicate that they occurred because of lack of time, of lack of energy (of the teacher), teachers' perception that later lessons were beyond students' comprehension, lessons were considered repetitious, students were more interested in later content in the unit, and the writing requirements were beyond the class skill level.

Sometimes teachers realised the difficulties that deleting phases may cause learners: 'Not having completed all activities made some classifying a bit tricky' (CD Tuk: *Explain* L5), but on other occasions the teachers implied that the phase may have been unnecessary, and this suggests that the purpose of the phase may not have been appreciated: 'This (*Evaluate* lesson) seems a rather simplistic activity to repeat—plant life-cycle—unless most students struggled with it initially' (T21 PA S2 *Eval*) and: 'Children were

25
See section 4.2 and appendices 4.1 and 4.2A and 4.2B outlining teachers' perceptions of limitations of the Primary Connections units.

26
WW, MM, ASS, SM, PA and SA.

27
A survey of the feedback frequencies for the *Evaluate* phase, and sometimes the *Elaborate* phase, (*see* table 3.2, shows that there was a distinct reduction in comments for the *Evaluate* phase in most units. This may mean that teachers had little to add about this phase; it may also suggest that several teachers did not implement it.

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'Overall, teachers and students enjoyed the Primary Connections units, and student learning in science advanced'

able to answer questions effectively without "doing" the experiment' (T16 WW *Exp*). In another instance, a teacher may also have felt some phases were unnecessary or may have selectively implemented components of phases while still addressing phase purposes (an acceptable approach as suggested in above): 'I skim and select points and lessons absolutely necessary for student achievement of outcomes' (T2G MM S3).

There is a key issue here. Teachers need to appreciate that each phase in the 5E model is necessary and must be completed in the recommended order in order to be most effective (Marek, 2009).

4.32
Apparent inappropriate application of a phase

There were several comments that suggested that some teachers may have been overlooking the main purposes of the phase. Some examples from different phases are outlined.

In an *Engage* lesson it appeared a teacher expected students to 'know' something about the content of the unit and hence did not use the TWLH chart; its purpose is to listen to any ideas the students wish to offer: 'Did not do (i.e., TWLH chart) as *children* had no idea about solids, liquids gases in beginning' (T1 SD S1). In an *Explore* lesson an 'expert' was invited. Their topic fitted with the focus on 'toys' but perhaps not the purposes of the *Explore* phase: 'Had a 'scientist in residence' who visited and talked to us about the science of toys' (T1 OM *Exp* L4). Other teachers appeared to provide too much input in *Engage* or *Explore* lessons:

> Guided part labelling session with worm drawing provided via photocopy. (T5 SZ S1 *Explore*)
>
> I drew a simple sketch on black board as children described what happens when it rains, extended this into simple water-cycle diagram and introduced terms—evaporation, precipitation and condensation. I downloaded a simple diagram for children to paste into books, I then introduced a water-cycle chart as children were interested and still asking questions (T6 Ww S1 *Exp*)

This possible inappropriate application of a phase may have included providing students with the 'Background information' (for *teachers*): 'Prepared students by sharing background knowledge with them' (T2 MM) and: 'L2 information was made into a cloze activity, which was used as a review of knowledge' (T22 MM).

If these inferences are correct then the impact of the 5E model will be limited. Marek's (2009) research review reported the impact of inappropriate actions in various 5E phases. Two examples are: providing conceptual explanations before experiences 'results in little or no conceptual understanding' and data obtained during exploration must be followed by discussion (p. 144).

4.4 Teacher understanding of the 5E learning cycle

As described in Chapter 3, a survey was distributed to about 60 teachers who had taught the first six Primary Connections units analysed in this project. The survey was a two-tier test of teachers' understanding of the purposes of the *Explore*, *Explain* and *Elaborate* phases of the learning cycle (Odom & Settlage, 1996). Although only a 20% response (n=11) rate was obtained, the results still raise questions for further reflection. A summary of the results (derived from Appendix 4.3) indicates that three teachers gave correct responses irrespective of reasons for 12 or 13 of the 13 items, while these same teachers had nine or ten correct responses with appropriate reasons for their response. This does suggest that many teachers may have a limited understanding of these phases. In this very small sample the *Explore* phase is better understood than the *Explain* or *Elaborate* phases. As an understanding of the purpose of the 5Es is related to the ways teachers implement the approach, then, if these responses are indicative, this aspect may need to be made more explicit for teachers.

4.5 The 5E model: discussion of issues raised in teacher comments

Several issues are raised in the above findings from teachers' comments after implementing Primary Connections units. Some of these are discussed next.

4.51
The tension between student interest and focusing on a central idea

Some teachers, while not critiquing the sequence, referred to student interests that arose and were sometimes followed by the teacher but not followed at other times. This must be a tension that arises regularly for primary teachers, that is, deciding on focusing on a central idea or on following student interest. Ideally, student interest can still be fostered while ensuring that key ideas are encountered within a 5E framework.

One teacher (T18 SS), referring to a TWLH task, indicated an interest that could not be fully followed, and this was partially the case for another (T17 EP):

> My children desperately wanted to learn about planets (T18G SS S2).
>
> Some wanted to build a model of all planets, space objects, satellites, etc. (T7 EP S3 *Exp*)[28].

Another, detailed how the *Earth's place in space unit* expanded in several directions:

> Students have been bringing in books from home, research from the internet, a cutting of the night sky Star Map from the newspaper. Our library Research-Based Learning task has been 'Should we send humans to Mars?' They have investigated what Mars is like, what the difficulties would be, some problems that need to be overcome, why should humans go there, what would benefits be to us, how would it affect Mars? Our design and technology large project has been to build a space station model. We watched the space shuttle Discovery's last voyage to the ISS on the IWB (T8 EP *Explore* L3).

It was clear from several other comments by this teacher (T8 EP) that their class did still focus on the main ideas in the unit.

28
This teacher (T7 EP S3) added later: 'More time needed to explore constellations and a link to mythology. One of the students wrote out the Greek alphabet as we digressed to stars and their degrees of heat. Also, eclipses came up with the question'.

In *Electric circuits* S3, following student interest was obvious in the teacher's comment below, but this teacher later indicated that in the *Explain* lesson, concepts developed have been well retained and employed by the students' (T19: EC *Exp*):

> Some students had heard the term superconductors and wanted to find out more about their characteristics. A small group explored this field of physics briefly via Internet. They developed a role-play depicting cooling of atoms. This spread the 'word' about resistance when their findings were presented to the class. We investigated plugs and cords as well as the dangers of 240v,'power stations' and transmission lines. An Energex linesman came to talk to the class. (T19: EC *Eng*)

The views expressed here (mainly by T11 SS) represent a more traditional (descriptive) approach taken by primary teachers, when 'Space' is the topic and developing student interest is aided by, as another teacher said, 'integrated topics' (T11G SS). The way that some teachers (and students) think about the 'purpose' of science lessons, will for some, be a stumbling block, when the 5E sequence is focusing on a major science idea over several lessons. It is not surprising, therefore, that these teachers (and students) might initially perceive the 5E sequence to lack student interest or constrain what content is covered. It signals a change in approach to science content that may require some teachers to adjust their view to science content from one of having their students encounter a wide range of science information (here information about many Space ideas) to a focus on meaningful understanding[29] of one key idea. Interestingly, the above teacher (T15 SS) who appreciated the merits of the narrower focus also thought the unit had 'flexibility to follow children's interests', which indicates that a focus on one key idea need not mean that teachers cannot follow the learners' interests.

4.52
Time as an issue for implementation

In many units time was an issue (e.g., CD S3 Ts 7, 8, 9, 10; also *see* Appendices 4.1 and 4.2), and this raises questions. To fully engage students in the various phases and listen and react to their ideas can be a time-consuming process—as one teacher expressed it, there must be time for students to reflect on what they are doing:'Giving students enough time to complete tasks; think about responses but not waste time was always on my mind.' (CD S3 T9G). Science learning does need to be seen as a heads-on as well as hearts-on and hands-on task (Skamp, 2007) for it to be effective across a range of learning outcomes.

For five units, several teachers provided details of the time it took them to complete particular lessons. These are summarised in Appendix 4.4. These data suggest that Primary Connections units take on average between seven to ten hours to complete. This would appear a reasonable time for a typical school term if one unit is implemented each term and especially if teachers can take advantage of the science literacy connections.

29
Meaningful learning is 'where the learner chooses conscientiously to *integrate* new knowledge to knowledge that the learner possesses (p.159 emphasis in original); it is characterised by being able to apply new knowledge to different situations to that in which it was leant'(Ausubel in Skamp, 2008, p. 49).

4.6 Implications for the implementation of Primary Connections and the 5E model

A summary of the findings and insights from this chapter are in Chapter 12, together with consequent recommendations.

Chapter 5

Implementation of the 5E phases: teacher-feedback analysis and findings

Introduction

In this chapter the focus is on teachers' comments as they relate to the specific phases of the 5E model. Each phase of the learning cycle has particular purposes. These have been outlined by Primary Connections (2008) and are in Appendix 2.1. Evidence as to whether these purposes have been addressed has been inferred from the feedback provided by teachers about the 'strengths' and 'weaknesses' of the lessons in each of the five phases in the 5E model. Teachers sometimes made comments about particular phases in other sections of the feedback pro forma (e.g., about resource sheets [RS]) and these were also a source of teachers' ideas. It is assumed that the teachers' feedback provides insights into what they thought were the most important aspects on which to comment.

The analyses for each phase will provide an overview of whether the teachers' comments suggest that the purposes of each phase have been addressed or not, and what appeared to facilitate the effective implementation of the phase, as well as whether there were difficulties in addressing the purposes. As outlined in section 3.3, responses needed to make direct reference to the purpose or expressed views that could reasonably imply whether the purpose was or was not met. Exemplar extracts are provided.

These analyses overview the responses across sixteen Primary Connections units. There are also brief comments on whether there appear to be any differences noted in teachers' comments across (a) units within different content strands, and (b) stages across content strands.

In the following, the reference to frequency findings reported about each phase is drawn from tables in appendices 5.1 and 5.2 (examples of these tables are tables 5.1 and 5.2). As stated above, responses needed to make direct or clearly implied reference to the purpose to be included in these tables. Views expressed about lessons that referred to other matters, such as difficulty with ICT and equipment issues, are not included in the tables. Overall, 206 teachers made comments across 16 units, although some teachers would have provided feedback on more than one unit[30].

30 The number of teachers who provided feedback on more than one unit is not known.

Table 5.1: Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

ON THE MOVE ES1 (N=10)

Phase	Purpose	Addressed	Addressed with difficulty or not addressed
Engage	Create interest and stimulate curiosity	5	2
(n=9)	Set learning within a meaningful context	2	-
	Raise questions for inquiry	1	-
	Reveal students' ideas and beliefs, compare students' ideas	4+[a]	1 or 2[a]
Explore	Provide experience of the phenomenon or concept	9	-
(N=9 max)	Explore and inquire into students' questions and test their ideas	>3[b]	1[b]
	Investigate and solve problems	5[b]	1[b]
Explain (n=7)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	1 (+1)	-
	Compare explanations generated by different students/groups	3	-
	Consider current scientific explanations	2[c]	
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	6 (+2)	-
(n=8)	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>2	3
Evaluate (n=6)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	6[d]	-
	Provide evidence for changes to students' understanding, beliefs and skills	2	-

a
It is probable that students' ideas were revealed in more responses. However, in one or two instances it is unclear as to whether the teacher provided definitions or examples of things that move, rather than simply eliciting students' conceptions.

b
Testing students' ideas was more likely than enquiring into students' questions. 'Greater than' (>) is shown because testing students' ideas, and investigating problems probably occurred in other teachers' classes. Students clearly investigated what happened with various 'movement' phenomena, but only in a couple of cases was it clear students were investigating whether specific ideas and 'solving problems'.

c
It was rare for teachers to actually refer to the conceptual area (in this case, 'movement').

d
Comments were mainly reviewed, not reflected upon.

INTERPRETATION OF THE TABLE

1. The frequencies are 'best estimates' from a reiterated interpretation of the responses, but inferences are sometimes drawn from limited expressions of teacher feedback. Where frequencies are in parentheses, evidence for the 'purpose' is more implied than direct, although the parentheses may also indicate that feedback on whether the purpose has been addressed is problematic. Frequencies are still included as it is more probable that the purpose was addressed, and sometimes footnotes are inserted to clarify their meaning. Where '>' is inserted it indicates the number cited could be higher. The frequencies are still indicative of the major impressions that the responses provide.
2. The 'N=' value associated with each phase is the maximum number of teacher responses that were made for any one, (or combination of), lesson(s) in that phase.
3. The frequencies cited for a 'purpose' within a phase refer to the number of different teachers who addressed the stated purpose in at least one of the lessons associated with a phase.

ENERGY AND CHANGE UNITS

Phase	Purpose	*On the move* ES1 N= 9/10	*Push-pull* S1 N= 8/17	*Smooth moves* S2 N= 9/11	*Electric circuits* S3 N= 16/19
Year trialled		October 05	Term 1, 2005	Term 1, 2008	Term 3, 2006
Engage	Create interest and stimulate curiosity	5	2	8	13
	Set learning within a meaningful context	2	1	0	>2
	Raise questions for inquiry	1	0	1	3
	Reveal students' ideas and beliefs, compare students' ideas	>4	1	>4 (+1)	>5
Explore	Provide experience of the phenomenon or concept	9	7	7	14
	Explore and inquire into students' questions and test their ideas	>3	4	>2	>7
	Investigate and solve problems	5	4	>5	>7
Explain	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4	5	6	10
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	1 (+1)	0	6	5 (+2)
	Compare explanations generated by different students/groups	3	0	>1	0
	Consider current scientific explanations	2	4 (+2)	>4	>8
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	6 (+2)	1 (+5)	1 (+1)	5

Table 5.2: Frequency of teacher responses suggesting if the 'purposes' of the 5E phases were addressed across four units in a strand

	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>2	>1	>1 (+4)	8
Evaluate	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	6	3	>3	>8
	Provide evidence for changes to students' understanding, beliefs and skills	2	1	1 (+1)	>4

INTERPRETATION OF THE TABLE

1. These summary tables have been derived from the more detailed tables for each unit: *see* Appendix 5.1.
2. The frequencies are 'best estimates' from a reiterated interpretation of the responses, but inferences are sometimes drawn from limited expressions within a teacher's feedback. Where frequencies are in parentheses, evidence for the 'purpose' is more implied than direct. Occasionally, there was a strong impression that several more statements implied the purpose was addressed, and a range is provided in parentheses to indicate this interpretation. Where '>' is used it indicates the number cited could be higher as interpretations were more problematic. The frequencies are indicative of the major impressions that the responses provided relating to the various 'purposes'.
3. The 'N' value is shown as X/Y. The 'Y' value is the number of teachers who returned annotated units for the stated unit. Usually this is the actual number, but sometimes it is an approximate number. It needs to be appreciated that not all teachers who provided annotated units included feedback that could be aligned with the content of these tables. The maximum number who provided relevant feedback in any one category on the supplied 'Trial Teachers' Curriculum Resource Feedback' questionnaire (e.g., strengths and weaknesses for lessons in the *Explore* phase) is shown as the 'X' value. Finer detail is available in the tables for each unit: *see* Appendix 5.1.

5.1 *Engage* phase

Four purposes are to be addressed in this phase. These are:

- Create interest and stimulate curiosity.
- Set learning within a meaningful context.
- Raise questions for inquiry.
- Reveal students' ideas and beliefs, compare students' ideas.

Teachers' responses indicated that each of these purposes were addressed or implied by some teachers across most units. Considering the nature of the data this, in itself, is a positive outcome as it probably means that all the Primary Connections units can meet the *Engage* purposes within a variety of contexts.

Tables in appendices 5.1 and 5.2 overview the range of response for these four purposes. They suggest that most units created interest and stimulated curiosity, with many identifying students' ideas and/or having students compare their ideas. Most teachers did not indicate that student questions were raised for inquiry. Although many teachers did not directly refer to 'setting learning within a meaningful context', the Primary Connections units generally suggested a 'meaningful context'; however, on occasions a few teachers did comment to the contrary.

5.11 Create interest and stimulate curiosity

More and strong endorsement of interest

Units which received the strongest endorsement for creating interest and stimulating curiosity and the least comments suggesting difficulties in meeting this purpose were *Water works* S1, *Material matters* S1, *All sorts of stuff* S2, *Change detectives* S3, *Schoolyard zoo* S1, *Plants in action* S2, *Marvellous micro-organisms* S3 and *Electric circuits* S3. Those receiving lower levels of response were *Spinning in space* S2, *Push-pull* S1 and *What's it made of?* ES1. Comments indicative of creating interest and stimulating curiosity include: 'Excellent response, children were very interested and highly motivated' (T1 EC and 13/16 had similar responses); 'Kids really excited. Some even made clothes for Garden Buddies' (T4 PA 9/10); 'highly engaging' (T20 CD 9/9); and:

> Children were very excited about this activity .... The children were so keen they spent lunchtimes with magnifying glasses looking for creatures .... Children enjoyed role-play' (T2 SZ S1 *Eng*)

Within these responses were indications of what created the interest. Features mentioned were: the nature of the *Engage* task (e.g., animal hunt SZ; bread testing MM); the strategies used (e.g., role-play SZ); the inclusion of a novel aspect (e.g., 'Green buddies' PA) or setting (forensic scene CD); direct involvement of many students' personal interests (e.g., their pets SA); a suggested technique (e.g., using a camera PA); and the content area (e.g., water Ww and *electric circuits* EC). In some units these features were frequently mentioned, such as Green buddies (9/10), indicating their interest value.

Sometimes the interest of the students surprised the teachers. This occurred with *Water works*: 'I was quite surprised how interested the children were in this unit. Water is a very real and relevant topic to the children ...' (9G) and *Smooth moves*: 'It has surprised me how the children have taken a difficult concept and understood it. Well done to the writers of the unit. A great unit'(1G SM). These responses suggest that content areas that teachers may believe are everyday (water) or difficult (forces) can still be of interest to students, especially if the pedagogy is well chosen.

Ambivalence about interest by a few teachers in some units

Contrary views from teachers were sometimes present when the content and/or teaching strategies may have been perceived to be less interesting, different from the norm or possibly difficult. A focus on forces in *Smooth moves* S2 had this effect as some teachers considered it boring (Ts 3,4,7) or too difficult (T7). This critical response also may relate to perceptions of appropriate pedagogy for science at the primary level: '[The children] should just be experimenting with the forces and gaining experience and having fun, not expected to complete such closed and complex experiments, tables etc.' (3G SM). This is in contrast to the above teacher (T1), together with eight others (Ts 1,3, 4, 5,6, 7,10,11), all indicating that student interest was aroused, for example:

> Children easily identified things in the room which could move and came up with suggestions to move the ball and container. They enjoyed the experiment, however, had many arguments about whether blowing the ball was direct contact or not. (T5 SM *Eng*)

'The children were so keen they spent lunchtimes with magnifying glasses looking for creatures.'

The value of a prerequisite unit appeared to have a positive effect in the following:

> The children loved these activities and particularly enjoyed the challenge of moving the ball bearing without touching it. These children did *Push-pull* previously so they were using terms such as push, pull and force regularly. (T6 SM *Eng*)

Creating situations in which students can 'argue' about science events may be quite different for some primary teachers. This may account for teachers holding different views about the value of discussion compared to hands-on tasks. Three *Smooth moves* teachers (Ts 7, 8 11) did indicate that interest waned in some parts of this phase, mainly due to extended discussion, but two also said interest was aroused (7, 11), with one seeming to imply the hands-on was of interest but not the discussion: 'The hands-on activity really got the students interested in the topic' (T11). A similar situation (in which teachers had contrary views about the role of 'talk', such as discussion) occurred in *Earth's place in space* S3, in which most teachers (10/15) reported that interest was aroused by engaging students in a debate about the movement of the earth, sun and moon, while three others found that their students disengaged as their lesson was too long and/or did not involve the students in physically active tasks. The contrast is shown in the following:

> Students really enjoyed making the models. This worked well. The idea of the argument was great—very engaging topic and led well into making the models. (T1 EP *Eng*)
>
> The lesson involved a lot of sitting down and listening and discussing and recording of ideas. There was a bit too much of the same type of activity and many students became restless and began to disengage. (T4 EP *Eng*)

Interestingly, in the *Evaluate* phase, another teacher added: '[B]ecause so much of the unit was hands-on and physical they remembered so much more' (T9 ES *Eval*). This tension between time allocated to hands-on and discussion tasks is discussed in section 8.3 (about the role of 'talk', as in discussion, dialogue and argumentation in learning science).

Less endorsement of interest and some difficulties

Those units that received the least endorsement, together with comments that there were difficulties in meeting this purpose, were *Weather in my world* ES1, *Spinning in space* S2, *What's it made of?* ES1[31] and *Push-pull* S1. Of these units, two teachers (from eight) said the students enjoyed the *Push-pull Engage* phase. However,

31
WM is listed here because of the low response for this purpose; only four teachers indicated that it captured students' interest in the *Engage* phase, but only one teacher (T9) referred to any issues (map reading was difficult for their students). It needs to be noted that frequencies were used here, not percentages, because of the low numbers involved and because percentages would give incorrect impressions.

these eight teachers did refer to time, preparation, classroom management and lack of student skills as factors that hindered the successful implementation of the phase. There was overlap in teacher thinking (about what is an appropriate balance between hands-on and discussion tasks) between this *Push-pull* unit and *Smooth moves*, with one teacher commenting: ‘My class are at the upper level at this stage and still needed a lot of play and experiment time’ (T5 PP). This view was perhaps more appropriately echoed by five (of 12) Early Stage 1 WW teachers (Ts 1,4, 9, 11,15), who felt the discussion was too long and/or was with unfamiliar content.

Contrasting views raise questions

Comments made about this purpose in other units indicate the wide variation in teachers’ opinions and that sometimes the same teacher offers different opinions. This has been alluded to in the above commentary. Another example is in *On the move* ES1 in which four (/9) teachers (Ts 1, 2, 7, 10) explicitly referred to how the *Engage* lesson motivated their students (children ‘love’ the musical statues (T7) and the moving mirrors (T2) and there was ‘good discussion’ (T2)), while two teachers (Ts 2, 8) commented students can lose interest if they believe they know what moves and what does not (T2) or that the discussion revealing ideas went for too long (T8).

This wide variation of teacher opinions is also shown in the opposite views held by some teachers who thought a unit did not fully engage interest: for example, in the *Spinning in space* S2 unit the *Engage* phase activities were ‘too babyish’ (T21) or ‘simplistic’ (T7), in contrast to the unit being ‘too complex’ and ‘abstract’ (T11G). To further complicate interpretations, the last mentioned (T11) said their students ‘enjoyed’ the *Engage* lesson.

5.12
Set learning within a meaningful context

‘Context’ can be interpreted in many ways, as can ‘meaningful’ or ‘relevant’. A common view (of context in this purpose) would be that the learning relates to students’ lives in an obvious way[32]. Teachers only made limited comments that could be interpreted as taking explicit actions (e.g., verbal comments about, or visual aids related to, everyday events) to ensure such a ‘meaningful context’ for learning was present. This could be because many of the Primary Connections units had embedded in their engage phase a meaningful context and teachers did not feel the need to reiterate this aspect; examples of such contexts would be exploring their school playground (SZ, WM[33]) and home garden (SZ), and investigating water sources and thier use at school and at home (Ww), or how a toy works (EC). In general, only two or less feedback remarks referred to this purpose (for each of the units; *see* tables in appendices 5.1 and 5.2). There were exceptions, including instances in which teachers made specific connections between the units’ content and the students’ world. Some examples of these exceptions are described in the following analyses.

Units where meaningful context was most mentioned

More teachers made specific and positive mention of context in *Plants in action* S2, *Change detectives* S3, *Smooth moves* S2, *Electric circuits* S3 and, to a slightly lesser extent, *Schoolyard zoo* S1. Students appeared to appreciate aspects of the learning context when items such as toys were introduced; they were ‘highly motivated’ in the

32
It needs to be borne in mind that many students would also believe their learning is ‘meaningful’ for topics that superficially do not appear to be related to their everyday lives, such as learning about the planets or dinosaurs.

33
As indicated elsewhere (*see* section 5.11), often there would be a teacher or teachers who held a contrary view; in this instance a WM teacher did not take her reception class into the school grounds as they felt their students were more familiar with materials in the classroom rather than outside. This still could be seen as the teacher deciding which context was more meaningful for the students. Another interpretation here could be the teacher was unwilling to move outside the classroom for other reasons, such as management or safety (e.g., *see* Skamp, 2009).

toy section of OTM (Tuk OTM ES1 *Eng)*. In EC, for example, one teacher 'brought in a variety of battery types and sizes—car, watch, AA, AAA, 9v (T17EC), while another 'used a collection of battery operated toys, which engaged the students straight away—Tickle me Elmo, Robots, and Remote Control Cars' (T16). Involving various home tasks and parents/carers added to the meaningfulness of the *Engage* phase in SZ and SA, and was mentioned by five teachers in each unit: 'Many families became involved' with students taking photos (SZ T17 and also T9) and: 'They enjoyed collecting information about their pets at home, and all students gave a presentation to the class' (2G SA).

Other units involved *Engage* activities that, most teachers implied, set the learning in a meaningful context. In *Change detectives* S3, students appeared to appreciate the learning context (being a 'change detective') and saw this as meaningful, although it may not have been directly related to their lives, as in: 'The idea of being detectives immediately encouraged the students to investigate' (T2 CD S3 *Eng*). In *Plants in action* S2, as the Green Buddies was set in the home garden, the learning context had implicit meaningfulness, which was implied in the teachers' comments under 'creating interest and curiosity' (*see* section 5.11). Investigating bread was clearly meaningful when children expressed 'surprise to find other ingredients in the bread' (T19 MM), and when a teacher reported how their class 'created (their) own packaging due to (a) diabetic child' (T21 MM). On occasions, a teacher mentioned how they directly related unit content to everyday events, as in relating the nature and uses of materials to 'lunchtime soccer play' (T10 ASS S2 *Eng*).

Units where perceptions of a meaningful context were less apparent

Although many teachers may have simply taken for granted that the context was meaningful and not referred to it, the opposite occurred when one unit was perceived to not less than a meaningful context. Several teachers (7/8) indicated the difficulties they encountered with time, management, lack of student skills and preparation, which suggested establishing a meaningful context was not uppermost in their thinking—this was in the *Push-pull* S1 unit. One teacher said they 'turned *Push and pull* into a transport unit context' (T8G PP), and this may have been because the teacher thought it would add more relevance to the unit's content. If a meaningful context is not established then this could detract from student engagement; for one *Earth's place in space* S3 teacher this may have been the case when they commented the *Engage* phase was 'too theoretical—needs to be more hands on and related to children's personal experience and understanding at their age. Many did not see connection of information in these sessions to space concept' (T6 EP *Eng*). For others in this unit this was not an issue as 10/15 teachers indicated how interested students were.

Other insights and comments about meaningful context

Insights into what teachers perceived as a meaningful context also related to: the physical location of the school, as in: 'Water is a very real and relevant topic to the children …' (T9G Ww S1); current events, for example: 'Used a rainy day to launch the unit, sat on verandah and watched rain, then did a concept map'; and links with related curriculum themes—one teacher 'did this unit in conjunction with "Parraraps" unit *Our Dry Continent*' and this same teacher also made reference to contact with other schools when they added: 'children participate in science investigations and share results on line with other schools, all worked beautifully, being *Year of the Drought*'. (17 Ww S1).

In the 'Earth and beyond' S2 and S3 units context was rarely mentioned, with only one teacher in each unit referring to a contextual connection, namely: '*X-files* to demonstrate no boundaries in space' (T1 SS S2) and: 'students had also seen [an] article on the TV news about solar flares on the Sun—interesting conversation' (T8 EP S3). However, this is an example of a content area in which 'meaning' is often thought of as intrinsic, in that students, like humanity, want to find out and understand, about our place in space (Skamp, 2012d).

In summary, 'Setting learning within a meaningful context' can take many forms. Curriculum resources clearly have some obligation to provide 'settings' that teachers can use. On the other hand teachers have a responsibility to show initiative in helping students see links between the science content and their everyday lives. The unit *Material matters* S1 is a case in point. It focuses on solids, liquids and gases, yet several teachers could not see the relevance of the unit, while one (*see* above) linked it with students' lunches. Making such connections may be even more imperative with some topics, like this one, as Qualter (1993), with a very large sample of primary students (n=3400), found that abstractions about solids, liquids and gases fell into the least-liked category of topics.

'The kids loved writing questions to add to the wall.'

5.13
Raise questions for inquiry

In all units teachers rarely made reference to questions that students raised for immediate or later inquiry. This purpose was directly mentioned most often in *Electric circuits* S3 (3/16 responses) and implied in *Plants in action* S2 (3/11) and in *Earth's place in space* S3 (6/14).

More obvious than in other units were two EC teachers' overall comments about raising questions. One said: 'The kids loved writing questions to add to the wall' (3G EC) and another: 'Students enjoyed this concept/means of displaying ideas and used sticky notes for questions, ideas and findings' (1G re Word wall). It was also implied in the *Engage* lesson when a teacher 'used 'Thinking strategies' [namely] 'I see; I think; I wonder' and [a] PMI chart' (T18EC). One teacher introduced an *Explore* task into the *Engage* phase and this also appeared to motivate students to raise questions:

> I used the information about Alessandro Volta and other scientists who contributed to the history of electricity at the beginning of the unit, as I wanted students to see how scientists worked in challenging ideas, investigating aspects of electricity to gain more knowledge and to explain how things work. I found this gave students a basis. The students then decided what they would like to find out about electricity and how they might go about doing this. Then I moved onto Lesson 1 where they investigated items they knew ran by batteries and followed that unit. (13 EC *Eng*)

Often, only one teacher in a unit mentioned or alluded to student questions being raised in the *Engage* phase. Their reports indicated what is possible. In *Spinning in space* S2 the phase did 'elicit a lot of ... questions' (T20 SS S2); in *Marvellous micro-organisms* 'children came up with some very good questions' (T3) and in

Smooth moves S2: '... because you are just "testing" the ideas that kids have, there is a certain amount of freedom in the discussion' (T4 SM *Eng*). In *On the move* ES1, a challenging question was raised when a teacher referred to a lesson step encouraging the elicitation of student questions for further inquiry when they said:

> LS22 (student's questions): great idea, except my first question was 'does God move all around the different planets?' (philosophical dilemma!?) (T4 OTM ES1 *Eng*)

In other units, questions for later enquiries may have arisen, even though teachers did not directly refer to them. In EP, for example, about half the teachers (7/15) referred to the thinking and the discussion that various tasks encouraged. As these comments sometimes suggested lengthy and animated discussions (e.g., 'continual discussions about [the] correct model from RS2 ensued through term' (T14 RP), it is probable that questions arose. This, of course, does not mean that they were recorded for later enquiries.

Raising questions and handling them: various issues

Raising questions was not always straight forward, as when an EC teacher commented: 'Step 11 ('I wonder ...') was encouraged, but had few responses from students' (1G). It is possible that few teachers' comments referred to this purpose because it is not a common practice to encourage students to raise questions; furthermore, when students do raise questions, perhaps teachers are unsure how they will handle them in terms of using them as the basis for later activities.

5.14
Reveal student ideas and beliefs; compare student ideas

This purpose relates to teachers *and students* recognising the ideas they already hold about the phenomena and concepts they are to encounter in the unit. Teachers should be especially alert to noting any alternative conceptions their students may express. It is also anticipated that students would compare their ideas with others in the *Engage* phase; this latter aspect was generally mentioned less than students revealing their ideas.

Revealing students' ideas

In general, more than a third of teachers made reference to addressing this purpose in the 16 analysed units. It was most obvious in *Plants in action* S2 (>7/11), *Earth's place in space* S3 (6(>3)/15)[34], *Schoolyard zoo* S1 (>6/18), *All sorts of stuff* S2 (>5/18), *Change detectives* S3 (>5/15), *Electric circuits* S3 (>5/15) and *Staying alive* S1 (5/15). Units in which it was less mentioned were *Weather in my world* ES1 (>1(1)/12), *What's it made of?* ES1 (1), *Material matters* S1 (3), *Marvellous micro-organisms* S3 (>2) and *Push-pull* S1 (1).

Elicitation approaches

Students' ideas were revealed in a range of ways in the various units; examples included:

- TWLH charts ('They knew a lot [and] ... used sticky notes to add to chart (TukG, PA; also T19 SS); others used similar approaches, such as the EC teacher whose class 'used sticky notes for questions, ideas and findings' (T17G) and the MM teachers who referred to the 'Global Analytical Super Sheet' [T5G MM], 'Jot

34
An explanation of the numbers and symbols is described with the tables in Appendix 5.1. '>' signifies that the number listed is the minimum number, and the general tenor of other teachers' comments suggests that the number could be higher (although there was not wording to that effect). A number within parentheses, as in 6(>3), means that there were six comments that were explicit or strongly implied the purpose, with three others that 'more loosely' suggested it.

Notes' [T18G MM] or 'Jot Thoughts' ('a Dr Spencer Kagan strategy') [T16G MM]);
- mind-maps (T2, T3 SS) including using *kidspire/ kidspiration* (T12 SS; MMat T5))
- brainstorming ('worked well' with the Mystery Bag *Engage* task [T4 PA; also mentioned by Ts 3, 12 EC]; and the 'things that move' brainstorm provided 'great responses' (T2 OTM *Eng*);
- partner discussion (T3 PA and T6 indicating 'Most were quite aware of cycle and parts') as well as class discussion (Ts 1,3 EC; on 'involuntary movement' (T1 OTM *Eng*), sometimes catalysed with hands-on tasks ('I started unit by having mouldy bread in plastic bags and children deduce what caused moulds by looking at ingredients on packet' [T8MM]);
- 'a scientists' chat board where 'junior scientific investigators' pinned notes about their latest … questions' (19G EC);
- drawing (leading to 'great … explanations' (T18 EC); 'Drawing positions and movement really showed what they did and didn't know' [T17SS]);
- a literacy writing task ('students individually record[ed] own understanding of how they move' [T9 OTM *Eng*]);
- a 'pre-concept survey' (T17 EC);
- a concept cartoon; and
- provided resource sheets (e.g., T15 SS said RS1 was an 'excellent assessment activity').

On occasions teachers did need to inject other activities to encourage students to offer their (own) ideas. In OTM, for example, 'Ss found it easier to identify things moving inside after being outside, [than] looking inside first. Trees blowing, cars moving demonstrated 'movement' for them' (8Eng OTM), while in ASS:

> 'Children did not have a lot of background knowledge about properties and materials. It took a lot of discussion for most of them to start to understand about using materials "for their suitability for a particular object". (T15 ASS)

In some units, teachers indicated students' ideas were identified with difficulty, as in *Push-pull* (*see* earlier comments about this unit in section 5.12). In some other units the difficulties experienced by a few teachers were: the students found the engage tasks too difficult (e.g., WW Ts 4, 6, 10 with one (T6) referring to difficulties students had in adding to the TWLH chart); lack of appropriate vocabulary with Early Stage 1 learners (T11 WM *Eng*); and non-familiarity with mind-maps, with a teacher indicating additional teacher scaffolding was required (e.g., 'did as a whole class, write ideas onto card and pasted onto mind map discussing suitable places' [T8 SS]). It was interesting to note the number of teachers (7/21) who had difficulties using mind-maps, generally thought to be a common tool used by teachers in a range of curriculum areas. One teacher (T15) actually commented that a 'concept map' would be 'easier', which many would think not to be the case[35].

As listed, one of the elicitation approaches used in EP was a concept cartoon. This did engage the students (T1, T11). An insightful suggestion was that 'a formal text may have helped (the students) compare the cartoon to what an argument text should look like with evidence to support the argument' (T1 EP). As 'evidence' was a major focus in the EP lesson sequence, there may be value in providing advice for teachers about different ways to facilitate student interaction with concept cartoons (e.g., Naylor & Keogh, 2007) and to engage students in scientific argumentation (*see* Chapter 8).

35
This teacher may have meant a 'mind-map'.

Appreciation of the value of elicitation

In commenting on the use of these elicitation approaches several teachers indicated their appreciation of the importance of this task, but only two formally referred to it being 'diagnostic assessment to see what the children already know' (T17 Ww *Engage* Resource Sheet 1; also *see* T9 EP below). Apart from in the above list, teachers, in general, added that these approaches 'assess[ed] prior knowledge' (T12 EC), lead to 'interesting discussion' and were 'informative' (Ts 1, 3 EC).

In this spirit of revealing students' ideas one teacher said: 'Did this without talking about concept of circle & arrows. Most put them in order—some in rows' (T7 PA), while a SM teacher appeared to encourage a range of ideas to emerge:

> Children easily identified things in the room which could move, and came up with suggestions to move the ball and container. They enjoyed the experiment, however, had many arguments about whether blowing the ball was direct contact or not. (T5 SM)

Cognisance of this *Engage* purpose was most evident in EP when about half of the teachers (8/15) either made direct reference to student 'misconceptions' or implied that they were identified:

> Making the models and then having to describe them and explain what they represented. A fantastic hook and a great diagnostic tool which showed me where they are at with regard to background knowledge ... [the students had to] re-enact the claims or develop a human model showing movement/rotation and have a narrator explain concepts such as effect on seasons, day/night etc. I did this prior to making orreries and the kids were better able to express themselves and created better models. It gave us the change to iron out some misunderstandings. (T9 EP S3)
>
> Good activity to uncover misconceptions. Students wanted to know correct answer! Interesting to see how thoughts differed. Important to allow students at this stage to have their own thoughts and not be influenced by others. (T3 EP S3)
>
> Lesson 1 was a real 'eye opener.' *All* students thought they knew it *all*. However, many misconceptions were identified, which were able to be recognised and amended by the students during the course of the unit. Cutaway diagram of earth was a good example as all are familiar with cutaway earth diagram. A useful assessment of developing concepts was to amend the original drawings in a different colour or highlight changes. Each amendment was dated. (19 EC *Eng*)

The first response (T9) is an exemplary indication of how a teacher encouraged their students to articulate the predictions that flowed from their mental models; the second indicates the teacher (T3) was, appropriately, withholding affirmation of students' responses at this phase. Some teachers found this difficult: 'The biggest challenge for me was not to correct their understanding or observations' (T9 CD *Eng*), a task many teachers find difficult (Glasson & Lalik, 1993; Grant & Kline, 2000). The third extract (T19) clearly shows the teacher appreciated that students also need to recognise their own existing conceptions (and return to reflect on them at a later time). An appreciation of the tenets of personal constructivism (e.g., *see* Skamp, 2012a) is apparent here, with the need to devote time to determining students' ideas. This can be illuminating for teachers not necessarily familiar with this theory of learning. Some SM teachers, on revealing students' ideas about how things move, were 'surprised by children's initial knowledge' (T1G SM), with another adding 'the children thought of far more ways to move an ice-cream container than I did' (T10 SM).

Focusing on students' existing ideas (e.g., recording them) can also cause anxiety for some teachers:

> Recording student observations was very difficult, so we talked about what we saw instead. The class really went off track when we writing up what we thought we knew about 'Forces'. *I fear the children will learn the incorrect thought as they are accepted and put on the wall. Upon reflection I feel I should not put the very incorrect answers up*. (T5 SM *Eng*, italics added)

This is a feeling experienced by other teachers initially using constructivist approaches (Gibson, 1992). It, along with other constructivist pedagogy and its underlying theory, may not always be fully appreciated, as when an EC teacher said: 'Not much content in this (*Engage*) lesson .... Needs to be longer' (14EC *Eng*) which (if compared to the above commentary around EC teachers' *Engage* comments) suggests that this teacher was unaware of how to fully explore students' existing ideas, and hence taught a short lesson. It also needs to be appreciated that elicitation takes time and that this is not a weakness as suggested by one teacher: (RS 1) took 'too long to complete as individuals' (T2 SS S2). It is also plausible that teachers who thought that the elicitation tasks may have been too easy, as in 'night and day too babyish' (T21 SS S2), may not be exploring students' ideas in depth through the various elicitation tools[36].

36
Many primary students hold a wide range of ideas about the causes of night and day (Brewer, 2008).

Ambivalent responses to the purposes of elicitation

Some teacher feedback was problematic in that students' 'prior knowledge' was identified (T11 EP) but it was not clear as to whether the teacher was simply identifying what they 'knew' rather than identifying alternative conceptions. This misunderstanding is implied when two teachers listed the following as a 'weakness' of the *Engage* phase, especially when identifying students' existing conceptions was one of its purposes: 'Misconceptions of day and night initially' (T16 SS S2) and 'Showed a surprising lack of knowledge or ideas' (T12 SS S2). Less problematic, but also where teachers may not have been focusing on identifying existing conceptions, was when students' ideas evolved in a role-play in which 'some students were very creative ... and brought background knowledge to the activity' (T5 SZ), and also when teachers reported students sharing ideas when they were observing animals in the *Schoolyard Zoo* and *Staying alive* units.

There were other times when teachers' interpretations of, or actions in, the *Engage* phase were also problematic. In ASS[37], for example, several teachers (4, 11, 12) did reveal students' ideas, but they may have implied that 'correct' responses were expected, rather than making explicit existing ideas and leaving the situation open. Two such ASS examples were: 'RS 1 A lot of students had difficulty with column 3, didn't write why material was suitable for this use but rather why the item was suitable' (T4 ASS) and: 'Children could complete column 1 and 2 correctly but many didn't address question in column 3 satisfactorily' (T12 ASS). This may have also been the case in *Material matters*, when three teachers commented on students' conceptions about classifying objects/materials in Lesson 1, with one adding they '... came up with very few scientific-type criteria' (T12), and others in which the students grouped 'inside/outside leading easily to Natural/Processed '(T14) and 'hard/soft, God made/man made' (T10). In all these cases, if these responses were accepted as a basis for further activities and later discussion then the *Engage* purpose has been addressed. In CD, a teacher possibly introduced

37
Interestingly, in this unit, nine teachers (Ts 4, 5, 6, 9, 13, 14, 15, 21, 22 ASS S2) mentioned how effective the fair test activity was, which may have revealed students' ideas about fair testing (rather than properties of materials), but this was not obvious.

terminology too early in the sequence: 'Many students were unfamiliar with the language that I was trying to elicit e.g., evaporate, physical changes, (chemical change was easy to get), melt (as in candle)' (T4 CD *Eng*). This suggests that in this unit, it would have been more appropriate to introduce these concept words later in the sequence, unless, as indicated, students suggested them.

The above interpretations and actions by teachers may indicate that some have expected too much too soon, or may have provided too much teacher input in the *Engage* phase. It is also implied in *Electric circuits* S3, when the invitation to a guest speaker may have provided input too early: '[We] organised a visit from an Aurora Energy Education officer to talk on hydro electricity' (T18 EC). Usually, outside speakers are recommended at later stages in constructivist sequences (e.g., *see* Biddulph & Osborne, 1984), although, as may have been the case here, they can add additional early motivation if briefed about their approach by the teacher.

38
This classroom attribute is expanded upon in later sections (e.g., 7.4 and 8.3).

Comparing students' ideas[38]

Compared to comments about revealing student ideas, teachers referred far less regularly to students sharing their existing ideas. Exceptions were *Staying alive* ES1, *Schoolyard zoo* S1 and *Plants alive* S2, in which five teachers (in the first two mentioned units) referred to students telling others about either their:

- pets—for example, at a 'sharing day' (T1 SA), 'the students showed a lot of interest in the pet profile chart and sharing info about their pets' (T7SA) and an '*All about my pet* booklet was used as part of our homework grid and presented to class showing pictures and writing' (T8SA);
- classroom invertebrates—for example: 'Great discussion to begin lesson' (3 SZ); 'Sharing presentations was valuable for all the kids' (T9); 'In my backyard project was enjoyed by all students. They presented their findings to the class'. (T10 SZ)

Sharing ideas was probably also apparent when teachers referred to good discussion (or similar) occurring. Examples included: a 'brainstorming activity' with a resource sheet (T6 Ww S1 *Eng*); when students were enjoying the 'discussion/debate' (T8); having 'lots of discussion' (T7); and 'lots of talking and trying to work out what happened' (T1) in the CD detective scene. However, in some of these instances, it is not clear whether teachers were simply helping students recognise their existing conceptions about change or encouraging sharing *among students* of *their* ideas. In a more explicit example, in *Push-pull*, the children 'were very keen to share what they already knew about pushes and pulls' (6SM) and 'enjoyed the experiment, however had many arguments about whether blowing the ball was direct contact or not' (5SM).

5.2 *Explore* phase

Three purposes are to be addressed in this phase. These are:

- Provide experience of the phenomenon or concept.
- Explore and inquire into students' questions and test their ideas.
- Investigate and solve problems.

Although slightly more teachers made comments about the *Engage* phase than the *Explore* phase, the total number of comments for the *Explore* phase far exceeded the *Engage* phase in that the *Explore* phase always had at least two lessons, and sometimes three (*see* section 3.3). When discussing whether the purposes of this phase were mentioned by teachers, the phase was considered as a 'whole' and not as separate *Explore* lessons.

Teachers' responses indicated that each of these purposes were addressed or implied by some teachers across most units, except for possibly one purpose in WW. Appendices 5.1 and 5.2 suggest that all units provided experiences of the phenomenon or concept. Most teachers did not indicate that students explored and inquired into their *own* questions and tested their *own* ideas, although there were units which were exceptions. In contrast, most teachers did report that students investigated and solved problems.

5.21
Provide experience of the phenomenon or concept

In all units most, and sometimes all, teachers indicated that this purpose was addressed (*see* appendices 5.1 and 5.2). Usually this phase involved observations and reporting, and sometimes predicting, testing and fair-test investigations (especially in MM)[39]. As teachers made many comments that related to this purpose, only selected exemplar comments from three units in each strand are listed. They are typical of the strand. If there were exceptions involving more than a couple of teachers, they are noted. Following these examples, WW is overviewed as it is an exception to the above.

39
See section 7.3 for more detail about SIS used in various units.

Earth and beyond

Water works S1

In Ww, responses from Lesson 4 (Water flows) indicated that the tasks which focused on water and its sources, uses and properties were 'really enjoyed' (T12; also T15); 'great (T13); 'a wonderful experience' (T5); 'This was a good activity, one group ended up with dough, children did this at home in sandpit' (T7).

Spinning in space S2

Students experienced the phenomena in the two *Explore* lessons associated with the Earth's[40] size and shape, and the formation and movement of shadows (and, as an optional task, the movement and 'shape' of the moon). Typical responses were that the 'physical aspects of the tasks (were) appealing' (T14), various tasks 'went well' (T3, T11), 'really engaged the children' (T16) and 'students were most enthusiastic' (T15).

40
This explains the two frequencies of '9' and '10' in appendices 5.1 and 5.2, indicating that there were nine affirmative responses and ten suggesting that the purpose was only addressed with difficulty or not addressed.

Earth's place in space S3

Many teachers (9/15 responses) indicated that students experienced at least one of the phenomena in the two *Explore* lessons associated with the movement (or apparent movement) of the Earth, Moon and Sun. However, there was a considerable contrast across the two lessons (Lesson 2 [4/15] and 3 [11/15]) and the two sessions within Lesson 3 (session 1 [3/15] and session 2 [10/15]; also, some teachers clearly provided 'experience' of the phenomenon/concept in one of the lessons but may not have in the other.

Natural and processed materials

What's it made of? ES1

All teachers (9/9) indicated that students experienced the phenomena, in this *Explore* lesson, associated with the properties of materials and from what objects are made. Typical responses, which were generally very positive, were: 'They're going around the yard pointing to objects and naming the material' (T1); 'Terrific information from children discussing different materials in classroom' (T2); 'Another exciting spare-time activity was matching objects with appropriate label' (T11).

All sorts of stuff S2

It may be assumed that all teachers who commented (18) indicated that students experienced the phenomena in at least one of the *Explore* phases associated with the properties of materials. All these lessons had a '(fair) testing' aspect that appeared to engage most classes, especially if effects were clearly observable and definitions of variables were straightforward. Typical responses, which were generally very positive, were: 'A really enjoyable activity' (T12, L2); 'Children loved this lesson and developed understanding of tensile' (T5, L3); 'Most fantastic lesson ever experienced. Step by step process was well paced' (T5, L4); 'The children loved this experiment' (8, L5).

It was also clear that there was a conceptual focus to these lessons, as several teachers referred to example concepts such as biodegradability (8, L2), tensile qualities (6, L3), hardness (7, L4) transparent and translucent (20, L5), as well as, on several occasions, the fair test concept.

Of interest are some of the issues particular teachers raised about difficulties with ensuring fair testing (e.g., operationally defining 'dent' or 'scratch' (T14, L4), transparent and translucent (Ts 12,14, L5), (cf. other teachers' similar experiences in Skamp, 2012). That these comments were made does indicate that the fair testing concept was being treated in a rigorous manner.

Change detectives S3

It may be assumed that all teachers who commented (eight in Lesson 2; nine in L3) indicated that students experienced the phenomena (of melting and other physical and chemical changes as well as role-playing particles). The particle role-play appeared to engage all classes. Typical responses, which were generally very positive, were: 'The students really enjoyed the role-play' (T6; *Explore* L2); 'Smelling the perfume, evaporating 10ml of water and melting activities were all terrific' (T8: *Explore* L2); 'They liked the ice cube melting challenge and we it used to critique the 'fairness' and, in particular, lack of controls and replicates in the test. Drama of particle theory popular' (T5 *Explore* L2); and: 'The students were amazed to see the evaporated salt water had mainly larger square crystals left behind and not the fine grains we had originally' (T10: *Explore* L3). The following clearly shows experience of the concepts related to change:

> We kept the solutions, evaporated the liquid and retrieved the salt. Initial discussion and chemical reactions and chemical change. An excellent session filled with wonderment and awe. The bottle that reacted gave the student a big thrill, after which we discussed chemical reaction and change. (T6: *Explore* L3)

Energy and change

‘We kept the solutions, evaporated the liquid and retrieved the salt …. An excellent session filled with wonderment and awe.’

Push-pull S1

From the teachers’ comments it may be assumed that most, if not all, of the seven teachers who commented across lessons 2 to 4 indicated that students experienced the phenomena of push and pull (forces) in various contexts, although several teachers commented on the time they took. There were contrary views about the Predict-Observe-Explain (POE) approach, with one class ‘automatically and easily using it’ (T1 L3), while another ‘had difficulty comprehending the model’ (T5 l3). A class had difficulty with ‘*Push-pull*’ words (T4 L2). Overall, though, several teachers commented favourably, with students ‘totally engaged’ (T10 L2), ‘discussion creating much interest’ (T17) and ‘hands-on investigation … excellent [but] messy’ (T1 L3). In Lesson 4 (about forces on objects in water) one class ‘had difficulty explaining why things float’ (T4) (while still enjoying the investigation) as did others: ‘Children could really feel the upwards push of water’ (T1 L4); ‘Session 1 was great. Kids really enjoyed it and it was an excellent experience of the push of water’ (T3) and: ‘Children enjoyed experimenting with water and getting objects to float and sink’ (T4).

On the move ES1

All teachers who commented (eight in Lesson 2; nine in L3; six in L4) indicated that students experienced the phenomena (of movement). Typical responses, which were generally very positive, were: ‘Drawing pictures of partner moving worked well; sentence writing quite easy but enjoyable …. Students enjoyed modelling different ways to move’ (T2 L2); ‘LS9: Played ‘musical statues’ again, but moving in ways discussed, took photos that students labelled’ (T8 L2); ‘Fabulous discussion about animal movement’ (T1 L3); and ‘LS6: Students discuss how toys move in pairs and share one example/pair with class’ (T L4). These four examples clearly refer to the ‘movement’ concept, but this was not always the case; for example, of eight teachers in L2 only two teachers (2, 8) explicitly referred to the concept ‘movement’. Some teachers added that the phenomenon/concept may have been overlooked due to the ‘activity’: ‘Teacher and students spent too much time playing with the toys, needed to spend more time looking at the “science” within the activity!’ (T10 L4).

‘Session 1 was great. Kids really enjoyed it and it was an excellent experience of the push of water.’

Life and living units

Marvellous micro-organisms S3

A comment that captures what many teachers felt about this unit was:

> … this proved to be a fantastic way to learn about micro–organisms/mould/fungi. The students were rapt, loved all the experimenting involved too. Helped them test and see if their predictions and logical thought processes were correct or not (19G MM).

This unit was unusual in that two teachers commented on the feedback item called 'writing investigation questions'. Some teachers added: '… the investigation was the focus of the sessions. The most successful activity for unit—yeast—excellent activity, students had sound understanding of outcomes' (T2 MM L2); 'An excellent lesson to ensure that students understand how to test scientifically' (T5 MM L2); and: 'Students excited and talkative about experiments' (T21 MM L2).

In the *Explore* phase, apart from the above, there were a few comments that students were designing their *own* investigations: 'Use(d) a scaffolding investigation sheet, to get children to think about what equipment they may need, rather than be told' (T12 MM L3) and:

> Children designed their own fair test using procedure from L2 as (a) guide. Came up with similar to RS2. Was great assessment of knowledge of fair testing and procedure genre (4MM L3).

The concepts of physical and chemical change were also mentioned or implied, as in: 'Children wanted to know about carbon and oxygen atoms and chemical reaction taking place'(T5 MM L4), with teachers also commending the learning value of 'procedural text' (T2 MM L2) and science journals ('to track change in scientific understanding') [T4 MM L2]).

Schoolyard zoo S1

It was obvious that all the teachers' comments indicated students had experienced activities with either worms, snails and/or ants, although there were occasional care and handling issues. Some teachers referred to concepts such as 'structure/ movement' (T9 L2; T16 L3), while many others mentioned observation and drawing outcomes.

Staying alive ES1

In the three *Staying alive* ES1 *Explore* lessons it was clear that eight (of the nine) teachers who responded to the feedback described students experiencing the 'senses' tasks, as well as the food, exercise and 'space and shelter' activities.

Relatively less reference to experiencing the phenomenon and/or concept

In *Weather in my world* ES1 seven out of 12 teachers made references to this purpose (i.e., 'experiencing the phenomenon and/or concept'), which was relatively less than (the proportion of teachers mentioning this purpose) in all other units. In *Explore* Lesson 2 this was probably due to either students not being ready to attempt the 'data chart' (Ts 11, 15 L2), 'a lack of hands on activity' (T3 L2) and/or 'children hav[ing] trouble coming up with the science words' (T16 L2). In Lesson 3 several teachers had difficulties and one (T13) omitted the lesson. Comments included: 'This lesson proved too difficult. I reduced it to talking about temperature; used the words hot, warm, cool and cold and we had pictures for each of these types of weather conditions. Children [were] encouraged to find out temperature at home' (T7 L3); 'too many new concepts at the one time' (T12 L3); '… Movement in and out of class with 28 takes a lot of time. Attention wanders quickly' (T15 L3); and '… it was not appropriate for Grade 2. We made up a different chart about cloud cover, temperature and wind' (13 L3). As has been mentioned previously, here as in other units, there were marked contrasting views about the implementation of particular Primary Connections lessons. This is shown in the comments of the following two teachers (in L2) and three teachers (in L3):

> The children loved being weather detectives. Engaged in observations. Weather terms taught are becoming part of their every day language. (T9 WW L2) (and later) … Children could easily identify with red & blue for hot and cold. They use the class thermometer to read the temperature. (L3)
>
> Looking in all directions was important as there was a difference in sky. Children really learnt the vocab on the data chart and used it. 'Look, it is overcast.' (T17 WW L2)
>
> Prior to lesson—good there is movement, hands-on and not all talk. (T4 L3)
>
> Used wheat pack and ice pack to demonstrate hot and cold. (5 L3)
>
> The students enjoyed moving along the temperature. (16 L3)

5.22
Explore student questions and test their ideas

It was less common for teachers in the *Explore* phase to make reference to explorations of students' questions and/or the testing of their ideas. In some units students did explore and inquire into their own questions, but there were limited numbers of teachers who referred to this course of action. On more occasions it was clearer that students tested their own ideas, rather than any questions they posed. In some units, when ideas were tested and questions were the focus of inquiry, it appeared to be the teacher or the Primary Connections lessons that were the source of ideas and questions asked (*not* the students).

*Strong indications that students' ideas were tested **and** their questions explored*

There were several units where this purpose was apparent, and others where it most likely occurred. The number of teachers referring to the purpose varied considerably, from *Water works*, where it was more common, to WM and SS, where perhaps one or two teachers made reference to it.

In *Water works* S1 some teachers, across all three *Explore* lessons, indicated students' ideas (predictions) were tested. Examples included: 'Session 1 went well with right balance of predictions, activity and observations' (T5 Ww L3); 'Session 1. Children very switched on and enjoyed the lesson, they had fun testing their predictions …'; (T17 Ww L3); '… predicted what might happen on different surfaces before watching as a class' (T11 Ww L3); and:

> Students enjoyed the water walk, became excited about spotting access points and amazed that number of points was so much greater *than predictions*, a lot of discussion. Students were very engaged with mapping points on school plan. (T3 Ww L2 italics added)

One of the above teachers (T11) said 'students were inquisitive about how the water cycle worked' implying students' questions were addressed. This teacher did report that the class then 'made a class poster, watched video and found (a) working diagram on CSIRO site of water cycle' as well as the above evaporation task. Others (Ts 6, 8), more explicitly referred to their students' questions becoming a focus, as in 'Constructed a terrarium to illustrate water cycle as prompted by children's questions' (T8 Ww L3) and:

> I drew a simple sketch on black board as *children* described what happens when it rains, extended this into simple water-cycle diagram and introduced terms—evaporation, precipitation and condensation .... I then introduced a water-cycle chart as children were interested and still asking questions. (T6 Ww L3)

Fair testing predominated in the *Marvellous micro-organisms* S3 unit, and it may be implied that at least seven teachers' comments suggested students were at least testing their ideas if not exploring their own questions, as in 'Step 2 resulted in very interesting ideas, children wrote own ideas in science journals to track change in scientific understanding' (T4 MM L3) and 'A very successful lesson, the visual results clarified concepts discussed, predicted by students' (T23 MM L3).

Two SS teachers (T15G, T20) specifically referred to students' questions, for example: '[T]his unit opened up some interesting discussions and questions' (T20) and provided 'flexibility to follow children's interests' (T15G), although the extent to which they were followed is unclear. Other comments implied that students were testing ideas, as in 'students were most enthusiastic about the compass activities and added directions to shadows' (T15) and 'loved shadow tag. Took photos of shadow changes .... Used strips of paper to record lengths' (T16). In the related unit EP S3 a few teachers did refer to students 'want[ing] to learn about (phases of the moon)' (T2) and 'wondering if they could graph the sunrise/sunset times' (T7), but it did not appear these apparent student questions were further explored.

In *Smooth moves* S2 at least two teachers suggested that students' questions were a focus for inquiry, as in: 'some students were beginning to see past the activities to the properties of magnets and to suggest other things to try ... as a result of this long exploration time ...' (T3SM L3) and most probably in:

> An excellent activity that worked well using the tomato cans. In working on defining a fair 'big and small' push we did averaging for the three small pushes and then the same for the big pushes. The data was excellent to view, especially when one of the three results was very different and asking why this was so (8SM L2).

Testing students' ideas was directly referred to by one teacher (T6—*see* extract below) and possibly implied by two others in: '(rubbing hands together) Really good activity'; 'Step 8 (pulling object across different surfaces) really easy for students to do and understand' (T11 SM L4) and 'Students enjoyed the rubbing hands and were fascinated by the black bits on their hands that everyone seemed to get from this activity' (T3 SM L3):

> The children were very engaged with this activity. Working outdoors was great fun and the children made some interesting comments about how they felt when stopping suddenly. The can activity proved very interesting. Some children were able to link the activity on the oval with the can rolling activity (as when) ... Jane (year 4) said, 'When travelling fast it is hard to stop just like when the can is travelling fast it can't stop. The can then moves the block because the block is in the way' (6SM L2).

Enquiring into students' questions was not as apparent in *Electric circuits* S3 but may have occurred when students were testing their ideas, a situation strongly implied by at least seven teachers in Lesson 4. The most obvious instance was when students engaged in the PROE (Predict, Reason, Observe and Explain) strategy:

> Students completed their own PROE record for their science journals, then contributed to a shared group PROE record for sharing in the class science journal ....

> Students redrew cut away diagram of torch and was interesting to see the growth in their understanding .... Such excitement when the first globe was lit! (3 EC L4)

In other classes students in Lesson 4 did 'circuit tests' (18 EC L4) and 'tr[ied] other ideas and were really engaged in this process' (13 EC L4). Further, students' conceptions were clearly the focus of investigation in this lesson where:

> ... discussion helped to bring many students' misconceptions to my attention, while the discussion (and) other students' diagrams and explanations assisted those with misconceptions to move onto scientific explanations. (19 EC L4)

In *Material matters* S1 this purpose was not apparent in most teachers' comments. However, reference to the TWLH chart (it was 'very successful' (T5)) does imply students asked questions. Another example implied students had posed a question and then enquired into it: 'Children enjoyed watching ice melt, extra challenge to see if they could make it melt faster' (T3, L4).

Other statements indicated students were most interested in others' ideas about how circuits worked, and this also implied testing their ideas: 'Drawing diagram on board (Step 8) ... children [were] very focused on what and how classmates were drawing'(T1 EC L4).

Units with more of a focus of students testing their ideas (rather than answering their questions)

Other units included the testing of students' ideas, but inquiries into their own questions was more problematic (although it still may have been present). Some examples from various units of where this occurred are provided.

As with EC, some teachers in *Push-pull* S1 used the POE (L3) strategy (but without the 'R'). This approach focuses on testing student predictions and was 'easily and automatically used' in one class (T1 PP L3) and most probably another (T4), but seemed to cause difficulty for some: 'Many children had difficulty comprehending the POE model. Many found the thinking way too challenging' (T5 PP L 3). Testing students' ideas was also directly implied in Lesson 4: 'Children enjoyed experimenting with water and getting objects to float and sink' (4 PP L4).

SZ

Testing students' ideas was more apparent with the worm activities than with snails and not with ants (probably due to the number of explore activities and practical issues). In the worm lesson two teachers indicated students tested predictions (Ts 2, 10), while others (Ts 4, 16 [L2]) implied predictions (or students' ideas) were tested before, in and after tasks. With the snails a teacher (T5 L3) also referred to a before, during and after task, while other teachers' (T7, 8 L3) comments may have implied testing of students' ideas. These likely outcomes are implied in some of the following: 'Students provided a variety of food, fabric to see what was more attractive to earthworms' (T10 L2) and 'Session 2—Children made some good predictions and we saw some soil/sand missing' (T2 L2) and:

> Before a close look and after a close look observations were very successful and promoted a lot of thinking and discussion. Earthworms were wonderful to observe and towards the end of the unit children found an earthworm in the playground and tried to save it using the knowledge gained from this lesson. (T4 L2)

‘Children enjoyed finding worms and looking closely at how they move and what they look like. It was amazing how detailed the students’ drawings became after using magnifying glasses to have a closer look.’

> Children enjoyed finding worms and looking closely at how they move and what they look like. (non–threatening) …. It was amazing how detailed the students drawings became after using magnifying glasses to have a closer look. Some children drew the saddle and wanted to find out more about it. (T16 L2)

CD

In one CD class:

> The students counted the number of seconds before they could smell it and also the number of seconds it took to evaporate—the porous newspaper was first but the students initially thought that this would happen to the white paper first—because it was cleaner. They recorded the length of time for the perfume to evaporate depending on the amount—1 drop, 2 drops etc. used. (T10: *Explore* Lesson 2 CD)

Later, the same teacher also commented:

> We added an extra bottle of straight water for this. We also dissolved a Panadol tablet as well as a Berocca tablet, as the results could more easily be seen. The students seemed to understand the chemical reaction that occurred. We also did teabags: one in hot water and one in cold water, and recorded the length of time before the water was coloured. (10: *Explore* L3 CD)

Testing ideas is obvious here (although in the ‘tablet’ extract it may have been the teacher’s ideas). In the following, it is also probable that various activities led to discussion related to the testing of (student) ideas: ‘Session 2 Step 5 Great questions! Both activities were terrific, very motivating and lead into all sorts of discussion’ (T8 *Explore* L3 CD) and: ‘One group did not follow steps so results were different to everyone else but this made for an excellent class discussion’ (T1 *Explore* L3 CD).

However, sometimes the excitement of these *Explore* activities may have impeded students’ thinking about the ideas behind the tasks:

> Students loved the balloon inflating and became competitive as to whose balloon inflated the most. I’m not convinced they focused on what was happening in the bottle (T5 *Explore* L3 CD)
>
> It was hard slog getting the children to at least accept that sometimes no reaction is just as much information as if the bottles had blown up. (T9 *Explore* L3 CD)

Moving from such explorations and testing of students’ ideas towards explanations (phase 3 in the 5E model) can be a grey area as one teacher reported in this explore phase:

> Explaining evaporation was *really* hard …. Explaining what happens when something evaporates—they never really got it … and the puddle (step 6) didn’t work at all. (8: *Explore* L2 CD)

Without knowing the context it is difficult to judge whether this teacher was finalising an explanation too early. Nevertheless, this comment emphasises the need for teachers to be aware of students' conceptions (as described in the Primary Connections Background information), as the literature clearly indicates that they may have difficulty explaining phase changes (Skamp, 2012c).

In *What's it made of?* ES1 two teachers (T5, T11) may have suggested this *Explore* purpose, as the following implies inquiring into students 'ideas': 'Session 2—this activity worked well. Had to discuss the options some people made and changed our ideas' (T5) and: 'Another exciting spare-time activity was matching objects with appropriate label' (T11).

As indicated earlier, teacher feedback from the EP unit rarely referred to students' questions. Testing their ideas was also difficult to discern in this phase, despite there being several opportunities where this could have happened, such as from evening observations and the 'My eyes deceive me' resource sheet (RS4) which encouraged students to test their own models of Earth, Moon and Sun movements[41]. Where it most likely happened was when teachers reported: 'We took some photos of each month and then shared them with the class. This was very powerful' (T1) and: 'The enormous number of varied misconceptions, such as in their orrery' (T10). The latter comment was when students had to revisit their orreries at the end of the *Explore* phase after considering movements of the Earth and Moon and what stars they can see from particular locations and various times. It strongly suggests this class was testing students' ideas.

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This comment indicates that irrespective of the intentions of a Primary Connections unit, teachers may not make reference to particular phase purposes in their feedback. Findings in this report can only comment on what was referred to by teachers.

Units where this purpose (i.e., testing students' ideas and inquiring into their questions) was not apparent

In three units this purpose did not appear to be implied. *On the move* ES1 teachers did not directly refer to testing students' ideas. It may have been implied when 'discussion' was mentioned (e.g., L4 = 3/7 teachers), but this may also have been discussion that was initiated by teachers rather than students suggesting their ideas to be tested. It may be problematic, as in 'LS7 (grouping activity): Excellent! Good for scientific knowledge and oral justification. Good thinking task' (4 L4 OTM); and:

> Optional LS9: Students given different-coloured Post-It notes (each colour indicates way of moving—swim/fly/etc). Post-Its stuck on animal pictures on wall to show ways of moving. Students realised some animals would have more than one Post-It (T3: L3 OTM).

For *Plants in action* S2 it was also difficult to discern comments that suggested students' ideas and questions were the focus. It may have been the students who, in 'Many creative ways suggested to overcome problems in this lesson' (T9 PA L3), but other comments indicated the teacher was making the decisions, for example, 'I put the seeds in individual cups in different directions' (T20 PA L3). Similarly, with *Staying alive* ES1 it was not clear that students were exploring their own questions and/or testing their own ideas (rather then the teachers'). It may have been implied in: 'They all noted the difference from before, during, after activity and we used this vocab' (5 SA L3) and: '… it was great to see the pictures and read sentences about the effects of exercise on their body' (8 SA L3). In this latter unit (SA), as some teachers reported, considerable discussion emanated from some activities, then this may imply that students' ideas and questions were a focus (as in, e.g., the senses tasks, as in: 'They enjoyed the interactive nature of the activity' (T5 SA L2) and ‘L2 This lesson worked well and lots of great discussion was generated’ (T7 SA L2)) but it is problematic in statements such as:

> Sensational trail—I made a trail in the garden for a student to walk through with a blindfold on. Another student was their guide and used verbal instructions and held their hand as they walked through. The students talked about the senses they had to use throughout the trail. (2 L2 SA)

However, overall, in SA *Explore* Lessons 3 and 4 teachers did not appear to include statements that connected to this *Explore* phase purpose.

Issues raised about the purpose of ‘Explore students’ questions and test their ideas’

In some of the units teachers suggested possible reasons for why students’ questions were rarely raised or explored. In the *Engage* phase it was mentioned that very young learners may have difficulty in this regard. In WM, in the *Explore* phase, six (of nine) teachers referred to students’ limited language and this may account for the few references to student questions, for example: ‘... (students) found it hard to guess material of object’ (T5); ‘Needed to go right back to basics with vocabulary—e.g. hard/soft’ (T7); ‘Took them a while to get the hang of the words (using descriptive words) (T10); and: ‘Children needed lots of prompting with descriptive words’ (T12). Limited vocabulary was also perceived by a few teachers as a stumbling block in MMat S1 where, for example, a teacher said: ‘Only one or two children could give examples .... Most students could sort into liquids, solids, gases but none could give the terms and, therefore, steps 9 and 10 had very little relevance to them’ (T9, L2). These difficulties align with teacher reports in the literature about properties of objects and materials, but there are ways forward (*see*, e.g., ‘language use’ in Skamp, 2012b). These responses do clearly indicate that students’ ideas were sought but that teachers rarely used the language of ‘testing students’ ideas’ or having them raise questions about objects and materials (apart perhaps for Ts 5, 7—*see* above).

In EP there are also suggestions as to why teachers may not have more regularly mentioned or implied that students’ ideas were tested. In this unit a few teachers indicated that students were not able to appreciate the role of exploring different mental and physical models (T12) (e.g., could there be more than one model that would explain observations). In other instances the teacher did not encourage their students to pose questions and/or explore ideas, as in: ‘Also they already knew how the Earth, Moon and Sun move in relationship to each other and couldn’t see the point in the activity (RS4 Part 2)’ (T12) and: ‘Taught the students about how constellations came into being but did not really engage them in higher-order thinking, explanation’ (T11).

5.23
Investigate and solve problems

This purpose was obvious in the *Explore* lessons in several units. As outlined in section 5.22 the ‘problems’ may not have been the students’, but many investigations still occurred and problems were ‘solved’.

Units where investigating was common

In *Water works* S1 *Explore* lessons, there were many clear instances of investigating in lessons 2 (Ts 3, 4, 5, 9, 17), 3 (5,11,17,1,3) and 4 (T12) as, for example, in:

> Students enjoyed the water walk, became excited about spotting access points and amazed that number of points was so much greater than predictions, a lot of discussion. Students were very engaged with mapping points on school plan (T3, Ww L2).
>
> Great preparation and lesson steps and experiments, students enjoyed doing these experiments, all went well with solid outcomes … [and later] did experiments for evaporation, watched clouds. Predicted what might happen on different surfaces before watching as a class (T 11 Ww L3).
>
> We froze one of the landscapes so the children could observe the change in water from liquid to solid and back to liquid (T12 Ww L4).

In *All sorts of stuff*, this purpose was addressed whenever the teachers referred to fair testing lessons (which was mostly very positive); this occurred often in four *Explore* lessons. Some comments were more explicit (Ts 2, 8, 10, 22 [L2], 6 [L3], and 22 [L4] and examples are:

'Great preparation and lesson steps and experiments, students enjoyed doing these experiments, all went well with solid outcomes …. '

> Worthwhile activity as children were amazed at own predictions at what did not rot (T2, L2).
>
> Also difficult to cut all materials into 'fair test strips' (it did become a good discussion, re fair test and tensile qualities) (T 6, L3).
>
> [S]tudents were able to identify new understandings. Many were surprised at the differences between predictions and results (22 lesson T4).

From sections 5.21 and 5.22 it is clear that *Marvellous micro-organisms* S3, *Electric circuits* S3, and *Push-pull* S1 units provided numerous opportunities for students to meet this purpose, with at least:

- ten MM teachers specifically referring to the value of fair testing and the various micro-organism experiments;
- seven EC teachers referring to students investigating to solve problems about how a torch works and completion of a circuit;
- seven PP teachers engaging students in investigating problems associated with forces, especially in Lesson 3 and (to a slightly lesser extent) in Lesson 4 which focused on forces in water and floating and sinking. In Lesson 3 the purpose was implied in five comments but directly in: 'Discussion at beginning prompted much interest … hands-on investigation was excellent; messy but excellent …. Students easily and automatically used the Predict, Observe & Explain process' (T1). Also, in Lesson 4 four teachers referred to, or implied, problems were investigated, as in: 'Children enjoyed experimenting with water and getting objects to float and sink' (4PP). The problems addressed appeared to be those the Primary Connections unit mentioned. Investigating problems was not as obvious in the other *Explore* lessons, with no clear examples in Lesson 2;

- five *Smooth moves* S2 teachers making reference to students investigating the impact of pushes and pulls, as well as the effect of friction. There were some exemplar instances of how students attempted to be fair in their testing of ideas:

  > An excellent activity that worked well using the tomato cans. In working on defining a fair 'big and small' push we did averaging for the three small pushes and then the same for the big pushes. The data was excellent to view, especially when one of the three results was very different and asking why this was so … [and later] some used a blackboard ruler like a pool cue and pulling back a certain number of cm in an attempt to define small and large pushes. Most did it successfully on the width of the table simply by pushing. (T8 SM L2).

It is worth noting, as one teacher remarked, that for such inquiries to be most effective, there is a need 'for proper discussion, questions, making sure instructions are understood etc.' (4SM L3)

Units where investigating may have been less common

Also, from sections 5.21 and 5.22 it may be assumed that most of the remaining units provided students with experiences of the focus phenomena but that, in general, their questions were not mentioned, although their ideas may have been tested. Further instances of this purpose (i.e., investigating problems and testing ideas) have been addressed in these units are outlined here.

In *Spinning in space* S2 four teachers implied that students were investigating and solving problems, as in: 'Children engaged good metalanguage and problem solving' (T3); 'Revised students' observations about shadows, resulting in wonderful discussions' (T11); and 'Students were most enthusiastic about the compass activities and added directions to shadows' (T 15).

Most *Schoolyard zoo* S1 teachers engaged students in observing, recording and discussing about their invertebrates, with some referring to testing predictions, and it can be implied that students also investigated and solved problems when teachers made comments such as: 'We were able to view an earthworm under our computer microscope as well' (T1 L2); 'Each group of students had their own worm viewer so they could observe them often' (T9 L2) and:

> Before a close look and after a close look observations were very successful and promoted a lot of thinking and discussion. Earthworms were wonderful to observe and towards the end of the unit children found an earthworm in the playground and tried to save it using the knowledge gained from this lesson. (T4 L2)
>
> Children enjoyed finding worms and looking closely at how they move and what they look like. … It was amazing how detailed the students' drawings became after using magnifying glasses to have a closer look. Some children drew the saddle and wanted to find out more about it. (T16 L2)

With the youngest learners it was clear that students did investigate some problems (and solve some of them), as this comment from the ES1 *Staying alive* unit demonstrates: 'When we were discussing our breathing and observing before and after physical activity we also used a stethoscope to listen to the heart' (T7 SA L3), but not many SA teachers' comments directly indicated that 'problems' were the focus. Also, in the ES1 unit *On the move* investigating problems was not usually explicit but it was implied in most remarks (probably with Ts 4, 9, and 2, 3, 7). As already stated, these were not necessarily the students' 'problems', but it was still obvious that they usually enjoyed investigating the problems presented in the Primary Connections lessons. Example comments included: 'Students enjoyed modelling different ways to move (T2 L2 OTM); 'Made graph of How Animals Move' (T7 L3 OTM) and:

> Optional LS9: Students given different-coloured Post-It notes (each colour indicates way of moving—swim/fly/etc). Post-Its stuck on animal pictures on wall to show ways of moving. Students realised some animals would have more than one Post-It; Optional (*Odd one out*): Ss found the Odd one out (100% correct), and also found something that moved the same way (less correct) (T 3 L3 OTM).

Units where investigating was far less commonly mentioned

There were several units in which investigating and solving problems seemed far less apparent. In some instances, there was still a focus on observing and recording, and in some instances, classifying, but not investigation in the broader sense (AAS, 2008a; Feasey, 2012).

'Children loved the mystery objects game. Children REALLY loved hands-on investigation. [It] allowed children to explore properties…'

In *Material matters* S1, this purpose was indirectly alluded to within some teachers' comments if sorting materials into categories is seen as 'solving problems' (L2): 'children did pick up sorting into solids, liquids, gases' (T1 L2) and 'used pictures from magazines to sort into three columns' (T6 L2). Lesson 3 (titled 'Exploring solids, liquids and gases'), though, suggested this purpose was more directly mentioned by one teacher: 'Children loved the mystery objects game. Children REALLY loved hands-on investigation. [It] allowed children to explore properties' (T11, L3, emphasis in original).

Similar to the above comments, *What's it made of?* also did not address this purpose, unless finding words for properties is considered a 'problem' or making predictions using the feely bag an investigation. If that interpretation is used then the following would suggest limited investigation occurred: 'Had to discuss the options some people made and changed our ideas' (T5) and: 'Children really enjoyed the feely bag activity, particularly the prediction' (T6).

For *Plants in action* S2, the focus of teachers' comments tended to be on students observing seed germination, plant growth and plant care, and not on solving problems (except perhaps in the example: 'Many creative ways suggested to overcome problems in this lesson' [T9 PA L3]). This narrower focus is shown in: 'Students focused on actual beans to write their observation report' (T1 L3); 'Used a variety of beans. Each kid had one cup and two beans .... Children loved watching the seed grow almost in front of their eyes (T9 L4); and: 'Each person had a cup and seed of their own to encourage responsible watering' (T13 PA L4).

Consistent with fewer comments about the first two purpose of the *Explore* phase (including none for the second purpose) very few teachers' comments in *Weather in my world* ES1 could be interpreted as implying students were investigating and solving problems, although it may have been present in some of the examples provided in section 5.22 (*see* Ts 9, 16, 17). In Lesson 6 some teachers commented how students 'loved being the weather person' (T11), but this does not obviously imply problem solving.

Following on from a lack of direct evidence for a majority of students exploring and inquiring into their own questions and testing their own ideas, it is not surprising that few teachers in *Earth's place in space* S3 made reference to students investigating and solving problems, although an exception would be:

> Star-crossed story and investigation using cut outs was a real hit. The students made awesome, moving models with their cut outs and wrote explanations which really showed they have pulled everything together so far. A brilliant activity. (T9)

5.24
Explore phase: discussion of issues raised in teacher comments

In most units there were real opportunities for students to raise questions, test their ideas and investigate and 'problem solve', yet the first mentioned was only occasionally referred to, while teachers referring to the latter two varied considerably across units.

Encouraging students to raise questions and handling students' questions

It is worth noting that only two teachers commented on the strengths and weakness of the 'Investigation Skills' section in the feedback pro forma titled 'writing investigation questions' (and then only to say it was read or an 'extremely useful guide' (T23 MM)). This could mean that very few teachers have considered how to 'turn' students' questions so that answers may be found by using SIS. Turning questions towards investigation is an acquired skill (e.g., *see* Harlen & Jelly, 1989; Skamp, 2012d), and even when questions were raised in some of the units it is plausible that some teachers may not have known how to handle them in this way.

In several units it was not clear that it was students' questions that were investigated. The 5E model underpinning the Primary Connections units requires that students will '... use science concepts to develop explanations for the science phenomenon' experienced in the exploration phase' (Hackling & Prain, 2005, p. 26). Therefore, it may not always be possible to follow students' questions and test their ideas; however, many teachers were able to encourage the latter and some the former. Apart from Primary Connections lesson steps that encourage teachers to be aware of student questions (as in the use of the chat board and other approaches or techniques), there is the goal of creating a 'question asking' and 'problem solving' ethos in classrooms. This was clearly present in some of the teachers' comments but not apparent in others.

Factors that may have influenced the successful implementation of the Explore phase

In general, this phase was very successfully implemented. Various *Explore* tasks tended to be more successful than others. In teachers' own comments, this would seem to be related to:

- the physical nature of tasks, especially with younger learners (e.g., using the senses in WM, SA), but still with upper primary years;
- readily observable changes occurring in the activities, such as 'dramatic change of early and late shadows' [T5, SS]); however it does need to be realised that, for

older learners, sometimes no change is also worth noting, as in 'no observable reaction when materials or substances are added together' as reported in CD;
- clarity and appropriate level of the conceptual ideas within the phase and that the suggested physical tasks directly related to these ideas (e.g., ball sizes and distance in SS);
- variety in activity type (as in SM);
- helpful questions in Primary Connections (T1, T2, T7);
- the value of the 'investigation planner'[42];
- simple equipment being required; and
- ICT suggestions that readily translate into classroom tasks.

Factors that may have hindered the successful implementation of the Explore phase

Teachers referred to several factors that they thought detracted from various Primary Connections tasks. These included:
- too much time devoted to discussion of ideas (e.g., T1 SA);
- complexity of ideas within parts of units (e.g., in EP, interpreting evidence from models of the possible movements of the Earth, Sun and Moon);
- ICT sites that either are inaccessible or not readily translatable into classroom tasks (as in EP);
- limited vocabulary or ability to use some skills (mainly younger students).

Of value to teachers in the *Explore* phase may be a guide to levels of scaffolding (e.g., Hodson & Hodson, 1998) and ways that teachers can handle students' ideas (e.g., *see* some of Harlen's teacher's roles in chapters 6 to 8 and Harlen, 2001).

5.25
The complexity of determining enabling factors: case study of the *Explore* phase in the EP S3 unit

Teachers implementing this unit offered mixed responses about its activities. It is unusual in that it incorporated a strong 'nature of science' focus in which students were introduced to the idea of mental, and their consequent physical, models, and then exploring and testing different models (that they were to suggest) in order to eliminate those that did not fit the observed evidence. This would not only be novel for many teachers, but also for their students, and may account for some of the limited opportunities available to students for meeting the requirements of the *Explore* phase. On the other hand, reading and researching about stars caused few difficulties; these, though, were not the major focus for these EP lessons. This is supported by the following teachers' comments, where they also suggest that only older or more 'talented' students could grasp the ideas:

> All the research/literacy based activities (e.g., about Galileo and constellations) were great. I don't believe that children this age are able to get as much from practical investigations on this topic as older children would. (T2, parentheses added)
> Some parts were TOO difficult for my yr 4/5s. It was grabbing the interest of talented students but those who struggle with literacy found many of the lessons challenging and boring. (T3 emphasis in original; here the teacher was probably referring to the references to various models etc.)

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Although across 16 units only 12 teachers commented on the 'investigation planner' in the strengths and weaknesses section of the feedback survey (with five referring to its value and others on wording/format etc.), overall it was apparent that a majority of Primary Connections teachers were familiar with fair testing, and the planner would have assisted in helping teachers scaffold fair testing and similar investigations.

In the following, the reactions of teachers to the model-testing tasks, a series of ‘constellation’ tasks and an at home night viewing exercise raise questions about how comfortable some teachers feel when the focus moves from exploring aspects of the ‘nature of science’ (beyond a superficial level), to a mainly literacy and creative visual design exercise, to a night-viewing homework task.

The NoS tasks: predicting and testing mental models using different physical models

To achieve these more novel (and difficult) goals, more time is probably needed—something that some teachers could be reluctant or unable to provide or may believe that students generating and testing their *own* models should not be the focus of the sequence (T9, T10): ‘Too much time focusing on misconceptions. Need more direct teaching of concepts. Models need re-thinking’ (T10). However, perseverance did pay dividends for one teacher:

> ‘Kids wanted to go back to own knowledge of solar systems and Earth rotating but this did help in last lesson, session 2.’ (T13)

Referring to the *Explore* phase, but also alluding to ICT difficulties, one teacher added:

> ‘this is taking a long, long, long time to complete’ (T5). Another, though, more directly mentioned that considerable guidance was required, which accounted for the time needed. A few teachers made similar comments:
> Lessons/sessions take much longer than available time allocated—often did not complete tasks. Had to re-teach most of group tasks as a whole class, giving very guided/specific instructions to obtain outcomes (T5).

There were three tasks in the *Explore* phase of EP. Two received more positive comments, but the first (mainly using resource sheet (RS) 4) caused considerable difficulties for some teachers (with seven listing ‘weaknesses’ and two listing strengths which did not obviously relate to the lesson’s main task). This task related to *predicting and testing using different models*. Eight teachers found RS4 difficult; it was reported as ‘confusing’ (T2, T11), ‘really tricky’ (T3) and ‘hard for the children to make connections’ (T1, T11). However, two teachers (T5, T14) indicated how much their students derived from RS4: ‘Students really loved this activity. Highly engaging’ (T5) and ‘Good, practical way to continue work on Earth’s role in space’ (T14).

One interpretation of these mixed responses could be that students (and teachers) may need perseverance for beneficial outcomes and that considerable scaffolding may be required. Two teachers (T1, T15) found that considerable guidance helped. One (T1) drew the whole class together for a discussion with an explicit example, while another said:

> They needed much discussion with [sic] me using lamp, globe [sic] following lesson steps 1–4 and again after discussing the experiment. At least there was comprehension on faces and comments the second time (T15).

This teacher (T15) added that the ‘experiment was hard to comprehend because movements of sun etc had to be on a flat plane’ (suggesting there were also practical issues that may not have been easily rectified in this class).

The literacy, creative drawing and internet interaction tasks

Students drawing their own constellation images was a task praised by several teachers, mainly because the children enjoyed it (7/15), although this was not universal as some students felt there would need to be a correct response (T4), while others could not see the purpose in the task (T9, T15), one seeing it just as an ‘art activity’ (T15). The latter responses suggest that ‘science as a human endeavour’ (ACARA, 2011) may not have been properly identified or stressed.

Reading about constellations received no negative commentary from teachers, with some indicating how much their students enjoyed it (T9). When an interactive internet site was successfully downloaded (e.g., Stellarium), then students enjoyed the task (Ts 3, 11); however, several teachers experienced ICT difficulties (Ts 5, 6, 12). It is of interest that very few teachers mentioned the hands-on task requiring observation and interpretation (namely, what stars can we see at particular times). It is problematic as to how many may have attempted this task. This is implied in: ‘Taught the students about how constellations came into being but did not really engage them in higher-order thinking, explanation’ (T11). When it was referred to, the response could be very positive:

> Star-crossed story and investigation using cut outs was a real hit. The students made awesome, moving models with their cut outs and wrote explanations which really showed they have pulled everything together so far. A brilliant activity. (T9).

However, this was not always reported, with one teacher saying: ‘Too difficult to monitor groups during groupwork tasks—many did not follow procedure to gain required understandings’ (T6).

The night viewing tasks: sky observations as a basis for later discussion and tasks

Several discussion and other tasks were dependent, to some extent, on students taking night observations as a homework requirement. This had mixed success, with some teachers reporting the difficulties that students encountered, such as late hours for observations (T4, T8, T9) and wet weather (T2), and others indicating only a minority of students completed the observations. However, when it was part of the sequence it appeared to have real value:

> We took some photos of each month and then shared them with the class. This was very powerful (T1).
>
> This was very well received—the only problem being that it is still daylight saving, so no viewing of stars till 8.00pm and a lot of students have to be in bed by 8.30. Some did find significant enough change in half hour timeframe though (T9 EP RS).

In summary, in this EP *Explore* phase, students did ‘experience’ aspects of the phenomenon/concept(s) to varying degrees, and this depended upon a range of factors. However, it was rare for teacher feedback comments to explicitly refer to students’ questions or that they were testing their ideas. There were several opportunities where this could have happened, such as arising from evening observations and the 'My eyes deceive me' resource sheet (RS4) which encouraged students to test their own models of Earth, Moon and Sun movements. Where it most likely happened was when teachers reported (as above, T11, repeated here):

> We took some photos of each (moon) month and then shared them with the class. This was very powerful (T1).
>
> The enormous number of varied misconceptions, such as in their orrery (T10).

The latter was when students had to revisit their orreries at the end of the *Explore* phase after considering movements of the Earth and Moon and what stars they can see from particular locations and various times. It strongly suggests this class was testing students' ideas.

It is worth noting that a few teachers did refer to students 'want[ing] to learn about [phases of the moon]' (T2) and 'wondering if they could graph the sunrise/sunset times' (T7), but it did not appear that these were further explored. Other responses indicated that students may not have explored other ideas as they were not able to appreciate the role of exploring different models (T12) (for example, could there be more than one model that would explain observations), or their teacher did not encourage their students to pose questions and/or explore ideas (T11):

> Also they already knew how the Earth, Moon and Sun move in relationship to each other and couldn't see the point in the activity (RS4 Part 2) (T12).
>
> Taught the students about how constellations came into being but did not really engage them in higher-order thinking, explanation. (T11)

5.3 *Explain* phase

Four purposes are to be addressed in this phase. These are:

- Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon.
- Construct multi-modal explanations and justify claims in terms of the evidence gathered.
- Compare explanations generated by different students/groups.
- Consider current scientific explanations.

The *Explain* phase always involved one lesson. Although all phases in the 5E model are important, this phase is pivotal (Marek, 2009). The *Engage* and *Explore* phases provide interest and experiences to get students thinking about how an aspect of their world works. Teachers are to *help draw together* (not necessarily directly 'explain', although this phase can include teacher explanation) the range of ideas that students have been encountering in this (*Explain*) phase. Students are then expected to apply and extend the conceptual idea that is the focus of the sequence in the next *Elaborate* phase before the teacher and students evaluate the success of the sequence, partially in terms of the conceptual understanding of the unit's central idea.

Teachers' responses indicated that each of these phases' purposes were addressed or implied by some teachers across most units. Appendix 5.2 overviews the range of responses for the four purposes. It, together with Appendix 5.1, suggests that all units used conceptual tools to construct explanations of the concept. All but two units included some teachers who used multi-modal explanations, and similarly all except three units had some teachers who involved their classes in comparing explanations from different groups. With the possible exception of WM ES1, all units included some teachers who ensured the scientific view was considered.

'The discussions around why we categorise were amongst our best of the unit.'

Although an analysis of whether these teachers addressed the purposes is presented in this section, the essence of the *Explain* phase is captured in this teacher's comment:

> The discussions around why we categorise were amongst our best of the unit. Whether it has taken this long to assimilate the information or the fact I was more comfortable seems to have had a bearing on this last component. There were no challenges. The children coped with this section very well. *I wonder whether it's because we 'revised' rather than added further investigations that the students worked very well with this notion of classifying* .... The students enjoyed *revisiting the earlier work they had completed,* such as the Mess Scene Investigation, and *remembering how 'revolting' the frozen milk appeared*. I also believe that whole sorting out process which the Changes card sort [sic] and their discussion allowed for placement *of what the students had been learning into organised understandings*. This activity was beneficial *because (it) organised their own concepts and gave them the time to do it.* (9 CD Italics and parentheses added)

Characteristics of the *Engage* phase emphasise that this phase is to 'provide opportunities for students to use their previous experiences to recognise misconceptions and to begin making conceptual sense of the activities through the construction of new ideas and understandings' (Bybee, 2002, p. 32). It stresses why it is important that this phase not be omitted, as was sometimes reported, as in: 'Opted not to do (*Explain*) lesson as bread issue is becoming monotonous, class wanted to grow moulds' (T6 MM) and '(*Explain*) lesson left out' (T13 MM.)

5.31
Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon

Range of conceptual tools across strands

Across all four strands teachers used at least 15 categories of conceptual tools in this phase[43] (*see* Table 5.3 and Appendix 5.3). The most common tool mentioned was teacher explanation and/or class discussion (n=37 teachers/across all four (4) strands), and referred to more in the 'Energy and change' strand. Other tools referred to by ten or more teachers were role-play/plays (n=17/2) but only in 'Earth and beyond' and 'Energy and change' strands, writing (unspecified, journal, explanation text, sentence completion) (n=16/4) and 3-D visual aids and/or manipulatives (n=10/4). Of interest is that ICT tools (internet, computer graphics/animation and PowerPoint) were referred to by seven teachers across three strands (not in 'Energy and change').

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These and other 'tools' may have been used in other phases, but the focus here is on teachers' comments in the *Explain* phase.

Table 5.3 Conceptual tools identified in *Explain* phase of the trial units*

Conceptual tool	Content strand	Teachers/strand	Teachers/ conceptual tool
Teacher explanation (TE)/ Talking/Class discussion	Earth and beyond	7	37
	Nat/proc materials	5	
	Energy & change	16	
	Life & Living	9	
Role-play/plays	Earth and beyond	5	17
	Nat/proc materials	0	
	Energy & change	12	
	Life & Living	0	
Writing (unspecified/ journal)/Sentence completion/ Explanation text	Earth and beyond	4	16
	Nat/proc materials	1	
	Energy & change	4	
	Life & Living	7	
3-D visual aids/ Manipulatives	Earth and beyond	4	10
	Nat/proc materials	1	
	Energy & change	1	
	Life & Living	4	
Flow chart/Graphs	Earth and beyond	1	9
	Nat/proc materials	5	
	Energy & change	0	
	Life & Living	3	
Drawing/Diagrams	Earth and beyond	3	8
	Nat/proc materials	1	
	Energy & change	4	
	Life & Living	0	
Pictures (charts (Ts/Ss)/posters)	Earth and beyond	0	6
	Nat/proc materials	5	
	Energy & change	1	
	Life & Living	0	
Storyboards (including pictorial)	Earth and beyond	3	5
	Nat/proc materials	0	
	Energy & change	2	
	Life & Living	0	
AV aids	Earth and beyond	2	5
	Nat/proc materials	0	
	Energy & change	0	
	Life & Living	3	
Listening (story/big book)/Reading	Earth and beyond	1	4
	Nat/proc materials	1	
	Energy & change	0	
	Life & Living	2	

* Conceptual tools mentioned once: Thinking hats (LL); Resource sheets (EB); Guest speaker (with visual aids); Computer graphics/animation (LL). For more details *see* Appendix 5.3

Internet (general)	Earth and beyond	1	4
	Nat/proc materials	2	
	Energy & change	0	
	Life & Living	1	
PM1	Earth and beyond	0	3
	Nat/proc materials	3	
	Energy & change	0	
	Life & Living	0	
Venn diagram	Earth and beyond	0	3
	Nat/proc materials	0	
	Energy & change	0	
	Life & Living	3	
Simulation	Earth and beyond	2	2
	Nat/proc materials	0	
	Energy & change	0	
	Life & Living	0	
Demonstrations (students)	Earth and beyond	2	2
	Nat/proc materials	0	
	Energy & change	0	
	Life & Living	0	
PowerPoint	Earth and beyond	0	2
	Nat/proc materials	1	
	Energy & change	0	
	Life & Living	1	

Variety in use of conceptual tools across different units

Some units used a wider variety of conceptual tools than others. In broad terms, these can be discerned from Table 5.4; a more detailed overview of these tools is shown in Appendix 5.3. In general, they show that some teachers showed real initiative in their efforts to facilitate understanding of the central ideas in the units.

Special tools used by some teachers

Some teachers appreciated the effectiveness of using presentations and 'representation', as in: 'Class really got into presentation of facts about plastic with a variety of class plays or shows' (T11, ASS); and:

> The representation options were great but needed more time, other lessons, to prepare the students. Teacher chose the graphs and PowerPoint. Sharing the representations with another class was a wow. Children had experience of sharing. (T6 PA)

'The role-play really demonstrated how circuits work and clearly showed the parts of the battery, electrons and globe play. This was an excellent activity to consolidate concepts discovered during L4.'

Table 5.4 Details of conceptual tools used in most units*

* All units are included in this table except for WW (as conceptual tools were difficult to identify) and PP, which is outlined in the text.

Unit (number of teachers mentioning tools)	Conceptual tools (with commentary)
Electric circuits (>10)	Role-play (1, 3, 6W, 12, 15, 16, 17, 18), discussion (1, 2, 12, 17), diagrams (4, 17, 18) (although role-play could be implied in all responses)
Earth's place in space (>9)	Writing (T3) and discussion (Ts 8, 9, 12, 15) around the resource sheet 7 (focusing on Galileo). These included revisiting the orreries (T7, T13), YouTube footage of Galileo's experiment (T11) and DVDs (T4)
Marvellous micro-organisms (>7)	Responding to questions/summaries (2, 7, 19, 24), including peer review summaries (5), internet usage (2), flow charts (23, 24) and microscope use (23)
All sorts of stuff (>7)	Exposition (4), websites, class plays and shows (11), discussion (22), posters (10, PMI (2, 6, 18, although 6 & 18 said not engaging), collecting materials (coded plastics) and graphing (6)
Smooth moves (>6)	Role-play (explicitly by 1,10, 11 and implied by 6), storyboard (4,7) and teacher explanation because of difficulties with concepts (4, 10, 11), although teacher explanation was implied in (1, 3, 4, 10)
Spinning in space (>6)	Wrapping 'a large map around student to demonstrate night and day' (T1), role-play (T2), 'drawing shadow on a map of the world then view from sun, moon, satellite from web site' (T5). 'team demonstrations' (T6), 'plasticene [sic] people to put onto globe' (T11) and a 'guest speaker from high school with light boxes' (T10)
Water works (>6)	Teachers referred to 'watery CD' (5), simulation, storyboards and flow chart
Plants alive (>5)	Reading (4) written summaries (4,12, 13), discussion (4, 5, 6), graphs, PowerPoint, modelled summaries, children share orally and then write (6), read books and background information to prepare students (4)
Schoolyard zoo (>5)	Venn diagram, thinking hats (14), discussion (1,3), reading (3) and movie (3, 4, 5), explanation text (5)
On the move(>4)	Charts, matching pictures with ideas (1), resource sheets (7), drawings (10), discussion (1, 7, 10) and writing/journal (9, 10)
Change detectives (>4)**	Graphing/measuring/verbal/written (1, 3, 5, 6)
Staying alive (>4)	Haptic activities and the use of a Venn diagram together with teacher discussion/explanation (including Ts 5, 7, 8)
What's it made of (>3)	'Class big book' which the class read (T5), 'pictures and words together' (T10) and 'large posters' (T11)
Material matters (>2)	Charts and posters (3, 11)***

** The *Explain* lesson, as in the trial unit, was used here; it became an *Explore* lesson in the final version.

*** Another teacher (in L4; not the *Explain* phase): Used diagrams of molecules to explain states (T1)–this is an interesting decision in that it precedes the *Explain* phase and is an abstract notion for S1 students (cf. Skamp, 2012b)

> Session 2 was used as a viewing exercise, techniques (animation, computer graphics) used to give animals human traits to help us understand how they live. (10 SZ)
>
> Used six thinking hats to explore how it feels to be different animals, Venn diagrams to identify similarities and differences. (14 SZ)

Role-play was most popular in EC and SM, and it is significant that at least one teacher mentioned discussion about the limitations of role-play. Some typical comments were:

> The role-play really demonstrated how circuits work and clearly showed the parts the battery, electrons and globe play. This was an excellent activity to consolidate concepts discovered during L4. (T3 EC)
>
> This was an excellent way to formalise the concept. They all wanted a turn to be the battery and globe. It was important to discuss the limitations of the role-play. (T17 EC)
>
> This was a terrific lesson, the kids loved the role-play .... It was a great way to see what they understood—or *didn't* understand—but because it was *Explain* stage we discussed it at length. (10 SM emphasis in original)

Of particular note in the EC unit were the four teachers who made adaptations to the suggested role-play (of what happens in an electric circuit) in Primary Connections, as in: 'I used buckets of water with chalk drawing of item. The chalk diagram allows for students to flow through the bulb Step 5, had students in line with some water in cup all ready' (T4), and the teacher who devised an additional role-play:

> Comparing conductors and insulators can also be role-played in a way similar to this unit but with coloured sports bibs on free electrons. Ask students to be free electrons or bonded electrons .... Instead of pegs, counters as packets of energy, used cards with E on them. Put LED on card for globe and anode and cathode on battery marked by cards with + or – on them .... Step 10 (battery using energy up) is a difficult concept for children, so demonstrated further with child pushing a marble along a groove with other marbles in it. When the child (the battery) stopped pushing, the marbles came to rest. The child had not used up the energy, it had transferred to the marbles with movement and sound. (T19)

Of interest, as the concepts underpinning an electric circuit are poorly understood by many (Hubber, 2012), is that two teachers commented that some of their students found it 'a bit basic' (T12) or could not see the point of the role-play (T6). This latter teacher did add though that follow-up discussion clarified issues around the movement of electrons and energy changes.

Scaffolding tools—going the extra mile

Although not referred to in conjunction with the *Explain* phase in EP, one teacher went to extraordinary lengths to assist learning that would have aided the *Explain* phase:

> We have a plastic orrery of the planets donated by a family at the school, an inflatable set of planets, not quite to scale, from the resource centre and a set of scaled planets and the sun loaned by our guest speaker from the astronomical society. The boys have also visited sites on the internet (T8 EP).

Less use of and/or difficulties in using conceptual tools

Interestingly, as forces can be a difficult concept to understand (Tytler, Darby & Peterson, 2012), *Push-pull* S1[44] teachers mentioned very few CTs except for sentence completion (1) and possibly writing (2), although teacher explanation was implied (Ts 10,1,3,4), as in:

> This was a great lesson. Students loved it. Not confident students understood the pull effect of gravity properly. Not certain how much to explain at this point. (10 PP L5; Gravity was a hard term for other classes as well (T4 PP)).

In a related unit SM, teachers needed to use extended explanations to help students handle concepts associated with forces and their representation:

> Students had difficulty understanding what was required of them and what was meant by forces. This took quite a lot of explanation and guidance and prompting to gather required knowledge and understanding. (T11 SM)

In some units there were difficulties with students learning different ways to express their understanding, and required modelling and other teacher scaffolding. Examples included writing summaries (Ts 23, 13 PA), developing a story board (T4 SM) and writing a narrative (T11, SM).

Explicit reference to evidence

Although interpreting evidence and constructing explanations overlap, it was rare for teachers to include comments that directly referred to focusing on ‘evidence’ per se, although it would have occurred in some lessons. Examples where it was more obvious were uncommon and some of these are outlined below.

Several EP teachers indicated students were appreciating the concept of ‘evidence’, with two (T3, T7) directly mentioning the term and two (T8, T9) implying its discussion:

> Developing understandings that scientists from the past are real people and their theories were based on evidence (T7 EP)
>
> Learning about Galileo—the students were fascinated, and appalled by the fact that somebody could be jailed for expressing an opinion—especially as it was true. They became quite obsessed with the injustice of it and it re-ignited their enthusiasm for the unit. (T9 EP)

Other teachers who made or clearly implied a reference to evidence were at least three CD teachers (Ts 5,6,9), as in: ‘This was an excellent challenge in terms of problem solving. We spent a lot of time generating ideas on what/how they could affect the candle and how long it would burn for’ (T9 *Explain* CD). In ASS claims would appear to be justified in several comments (Ts 4, 6, 10. 11, 22 and probably 2); examples include: ‘With all (the) background on plastics, students were able to write well reasoned expositions (T4); ‘Nova website useful for information for PMI .... Class really got into presentation of facts about plastic with a variety of class plays or shows (T11); ‘Students peer review summaries using a comment sheet with headings—What you did well, Some suggestions’ (5MM).

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The impression was that five teachers had no real difficulties with this lesson but two found providing explanations at an appropriate level difficult and/or challenging (Ts 10, 1, 3), e.g., ‘I still don’t understand how to model downward pull with an arrow as this makes me think downward push—then I don’t really know any other way to show it’ (T1 PP)

5.32 Construct multi-modal explanations and justify claims in terms of the evidence gathered

There is growing evidence that encouraging students to represent their understanding in more than one mode assists conceptual development (Tytler & Prain, 2010); furthermore, teachers can scaffold learning by using more than one mode. The forms that modes may take include descriptive (verbal, graphic, tabular), experimental, mathematical, figurative (pictorial, analogous and metaphoric) and kinaesthetic (embodied, e.g., use of gesture, and physical action). Some tasks, by their nature, will include more than one mode, such as role-play or simulation (e.g., movement and verbal).

Units in which individual teachers mentioned more than one mode in facilitating students' conceptual understanding are summarised in Table 5.5. The units in which most teachers used a multi-modal approach were EC (n=10/at least three (3) combinations of modes), SS (n=6/5), SM (n=6/2) and CD (n=4/1), and three of these units were very popular with students and teachers. Of interest is that two units that received mixed comments from teachers (WW, PP) included no comments that referred to more than one mode in this phase; in both cases some teachers referred to conceptual difficulties experienced by some students. Further, across all the units, examples can be found of most (if not all) modalities, including kinaesthetic. Although the content area can affect what modalities might be considered, this does suggest that many modalities could be used in most content areas.

A few examples supporting the data in Table 5.5 have been previously mentioned, for example, role-play in EC and SM and representations in PA (*see* section 5.33). Other instances include:

> Session 2 was used as a viewing exercise, techniques (animation, computer graphics) used to give animals human traits to help us understand how they live. (10 SZ)

One *On the move* teacher (T10) devised tasks that required verbal/written, visual, spatial and kinaesthetic abilities:

> Adapted by Teacher (3 rotations): 1. Discuss and demonstrate how toy card moves 2. 'Sam' the skeleton—move Sam's body and copy how he stands 3. How animals move—trace animals from tracers and write 3 words about how [an] animal moves (10 *Explain* L5 OTM)

Other issues about using multiple modalities

As stated, students do seem to learn more effectively if explanations include more than one mode (e.g., *see* Tytler, Prain & Peterson, 2007). As role-play is usually considered an effective conceptual tool (if its conceptual limitations are discussed), it was surprising that two teachers in SS deleted it, with one (T18) suggesting that it was 'overkill'. This may indicate that multi-modal representations are not considered necessary; this teacher did say though that the 'circle was very helpful as was globe on chair'. Another teacher (T21) appeared to have management issues with the role-play, saying: 'Role-play didn't work well, children bumping into each other and misusing their knowledge of how Moon, Sun, Earth move in space' (T21 SS L4). Clearly, patience is sometimes required, and pervasive management may be of assistance (Harris & Rooks, 2010).

Table 5.5 Number of teachers who explicitly referred to explanations in more than one modality* (multi-modal) in *Explain* phase

Unit	Teachers	Examples of multi-modal explanations
Electric circuits S3	10	Role-play (1, 3, 6W, 12W, 15, 16, 17, 18) kinaesthetic/diagrams (4, 18) kinaesthetic/discussion (1, 2, 17)
Spinning in space S2	6	Role-play (2, 8) Role-play/demonstrations (19) Drawing/internet (5) Talking/3-D (10) 'Children came up with heaps of ways to demonstrate' (6)
Smooth moves S2	6	Role-play (1, 10, 11 [6]) Role-play/story board/narrative (4, 11)
Change detectives S3**	5	Graphing/(assumed) discussion (1, 3, 5, 6, 9)
Staying alive	4	Haptic/discussion (5, 8) Haptic/drawing (7) Haptic/writing (6)
Schoolyard zoo	4	Visual (film/computer graphics)/discussion (3, 5, 10) Visual (Venn)/discussion (14)
What's it made of? ES1	4	Visual (e.g., big-book)/linguistic (talking/writing) (4, 5, 10, 11)
Material matters S1	4	Discussion/posters (1) Charts/posters (linguistic/visual) (3, 5, 6)
Earth's place in space S3	3	3-D/talking (7) 3-D/writing (13) Visual/talking (8)
Marvellous micro-organisms	2	Talking/writing/internet (visual) (2) Writing/visual/discussion (flowchart) (23, 24)
Water works S1***	2	Talking/writing (11); drama/storyboards (15)
All sorts of stuff S2	2	Poster/discussion (10) Internet/PMI/Presentations [plays/shows] (11)
Plants in action	2****	Linguistic/auditory (talk/write) (6) Graphical/PowerPoint (verbal/visual XX) (6)
On the move ES1	1	Discussion/demonstrate (kinaesthetic/visual)/written (10)
Weather in my world ES1	0	-
Push-pull S1	0	-

* Modalities can include verbal (spoken or written) or non-verbal (movement [kinaesthetic], touch [haptic], visual and auditory.

** The *Explain* lesson in the trial unit became an *Elaborate* lesson.

*** The *Explain* lesson in the trial version (L4) was replaced by L5 which was originally an *Elaborate* lesson. The data in this table refers to the original *Explain* lesson (i.e., L4).

**** Two teachers commended the representations, but did not indicate what they used.

5.33 Compare explanations generated by different students/groups

Often, this purpose was not directly mentioned[45], although when discussion occurred it may have eventuated. Discussion/conversation was mentioned (or strongly implied) with different degrees of frequency in different units, for example: *Weather in my world* ES1 (T1); *Water works* S1 (T11); *Earth's place in space* S3 (Ts 8, 9, 12, 15); *Material matters* S1 (T9); *On the move* ES1 (Ts 1,7,10); *Electric circuits* S3 (1,2,12,17)[46]; *Staying alive* ES1 (Ts 5, 8); *Schoolyard zoo* S1 (Ts 3, 10, 14); *Plants alive* S2 (T6) and *Marvellous micro-organisms* S3 (Ts 5,2,24). At other times, teachers did not directly make reference to discussion or students sharing explanations, although it probably could be implied if students were involved in role-play and similar activities. Units where this may have been the case are: *Spinning in space* S2 and *All sorts of stuff* S2, where it was apparent with some teachers (Ts 6, 11, 22), as in student presentations.

At times, the sharing of students' explanations was more explicit, but often there was only one teacher within a unit that mentioned it. These instances were in:

- *Marvellous micro-organisms* S3 (T5): 'Students peer review summaries using a comment sheet with headings—What you did well, Some suggestions';
- *Plants alive* S2 (T6): '… Sharing the representations with another class was a wow. Children had experience of sharing';
- *Smooth moves* S2 (T10):

  > This was a terrific lesson, the kids loved the role-play, but boy it takes up a lot of time, particularly the role-play, because everyone wanted to show everyone else what they did (all nine groups). It was a great way to see what they understood—or *didn't* understand—but because it was *Explain* stage we discussed it at length. … Many of my kids did not know about energy;

- *Staying alive* ES1 (Ts 5, 8): 'We placed items into Venn diagram and we had lots of discussion about whether mobile phones, magazines, sunglasses were really needed' (T8) and: 'The kids got the idea well and we had an in-depth discussion about their choices. They're experts at working with learning teams and did a great job on this too' (T5);
- *Water works* S1: Possibly three teachers implied a wider sharing, as in the drama simulation (T15) and 'Great lesson, children confident about talking about water cycle, had a great time at writing a water story' (T11) and: 'In English, used felt boards for additional motivation, recorded conversations with buddy class' (T1);
- *Earth's place in space* S3: It may be inferred from four teachers' comments that students listened to others' explanations. Examples included a class who 'couldn't understand why people didn't believe him (i.e., Galileo)—from their perspective of looking back to that historical time. They felt he was hard done by' (T8); another where 'it helped dispel a few myths' (T15);
- *Change detectives* S3: This was not obvious but was probably present in: 'Some of my weaker students floundered during this investigation and relied very heavily on those students in the group who had a better understanding. Generating ideas for group investigation was a slow process' (T9: *Explain*).

Units in which no teachers directly indicated that explanations were compared were WM ES1, *Push-pull* S1 and probably *Weather in my world* ES1.

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Of course it can occur in any phase, as in the following, but the focus here (section 5.3) is the *Explain* phase:
Evaporating the 10ml of water was terrific, so many ideas were generated and discussion was amazing. Smelling the perfume, evaporating 10ml of water and melting activities were all terrific. These three sessions were terrific but took a lot of time. The children generated a lot of ideas and their enthusiasm for doing something so basic was amazing. They got a lot out of the experiments and started to draw conclusions and offer explanations. (T8: *Explore* L2 CD)

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In EC and units where role-play was used students probably generated explanations, but it was not stated.

5.34
Consider current scientific explanations

In determining if this purpose was addressed or implied two categories were developed. If teachers made some reference to the conceptual content in the unit in the *Explain* phase then it was considered to be evidence that the scientific view was part of the teacher's thinking. If other comments suggested that the conceptual content was addressed but there was no mention of the content, then a judgement was made as to whether the scientific view was implied. Appendix 5.4 summarises these two categories.

Units where the scientific view was most obvious were EC, ASS, MMat and CD, followed by *Smooth moves* and *Push-pull* , while teachers did not appear to mention this purpose in WW and WM, and rarely in OTM, SA, PA and MM. Although not consistent, it may be that teachers in lower primary years are not focusing on students organising their thinking around the units' key conceptual foci as much as upper primary years teachers. Other possibilities for these differences could be that: firstly, some Primary Connections units' science conceptual foci are more clear cut, as in concepts and understandings like electric circuit (EC), solids, liquids and gases (MMat), properties of materials and their uses (ASS), physical and chemical change (CD) and forces (PP and SM); and, secondly, there were distracting factors that moved the focus elsewhere, as in simply watching seeds germinate and plants grow (PA), or some teachers having difficulties with implementing units (EP). In some instances, though, when teachers and/or their students found the concepts challenging, they focused more on the key ideas with their students; as indicated in some comments from the PP unit.

Teachers generally commended the Primary Connections explain strategies that were suggested to help students 'organise' their thinking towards the conceptual focus of the unit. Appendix 5.4 suggests that formation of the scientific view was especially assisted by role-play in EC and sorting tasks in CD, as well as, when required, teacher explanation (PP and SM). Choice of the most effective strategies will, to some extent, be dependent on the nature of the science concept or understanding, as these examples show.

Teacher actions in ensuring the scientific view is considered need to be subtle. The 5E model does not indicate that the scientific view be 'transmitted' to students. Rather teachers help students clarify their thinking in the *Explain* phase; students are active learners in all phases of the 5E cycle, an interpretation emphasised in early research related to the learning cycle (Glasson & Lalik, 1993). It would seem from teacher comments that this approach was appreciated as there were no suggestions that direct transmissive teaching occurred although teacher explanation had its place when required.

5.4 *Elaborate* phase

Two purposes are to be addressed in this phase. These are:

- Use and apply concepts and explanations in new contexts to test their general applicability.

- Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics.

The essence of this phase was summed up by a teacher who said: 'It was good to apply tests and understandings to different situations' (T1, PP). In this phase, some teachers' comments indicated they appreciated this requirement, while many others left it unsaid. The following exemplifies what could be possible in this phase, if teachers are cognisant of its key purpose.

Vignette: the essence of the Elaborate phase

In SM, a teacher directly commented that force ideas were being applied in the *Elaborate* phase. This teacher had taught the *Elaborate* phase with an earlier class and it was not very successful. Here, a variation on the Primary Connections' ideas for fair testing was implemented. However, the value of, firstly, giving students 'exploration' time to overcome the excitement of handling tempting equipment (here, catapults), and secondly, varying the fair test, resulted in students engaging with the '*Push-pull* forces' as they were investigating (but it needs to be added this occurred after discussions about forces [albeit, less successful] earlier). This suggests that, on occasions, exploration time with materials may be needed and then firm boundaries set before fair testing can effectively focus on key concepts, and, perhaps more importantly, that teachers need to have *these key concepts uppermost in their minds* (as this teacher did):

> With my other science class, after the disappointing results with my own, I approached 'catapult capers' differently. After setting strict boundaries and being very explicit about safety issues .... I set them the task in their teams of competing with each other to move an eraser the furthest, then to figure out how to make it go further. They could then try out different-sized rubber bands. The scientific ideas and discussions that came out of this far excelled any my class had when trying to complete the lesson as set out in this trial unit. One group began inventing games (knocking counters into a container etc.) which sparked *conversations about different games involving these forces*. We all felt very satisfied after this. (3 SM italics added)

This teacher did the above after:

> Giving the students 1 hour lesson of 'free play' with 'catapults'—soft missiles—before trying the exercise twice—once with staplers which was not successful, then with rubbers which wasn't really any better. Basically the physical tasks were too hard to do accurately (holding the rubber band and ruler in place—pulling back accurately etc. and *because they didn't ever really engage with the whole pull-push forces deal* (except the magnets) all they wanted to do was flick things with the rubber bands. (3 SM)

The *Elaborate* phase involved between one and three lessons (*see* section 3.3). One of its main aims is to 'apply or extend the students' developing concepts in new activities and relate their previous experiences to the current activities' (Bybee, 2002, p. 32); its meaning has also been expanded to embrace the further development of students' understandings as 'they engage in divergent problem solving' using the additional 'resources and experiences' they have gleaned from earlier phases (Glasson & Lalik, 1993, p. 203).

Table 5.6: Frequency with which teachers mentioned students using, applying and testing concepts and explanations in new contexts in *Elaborate* phase

*
X is the number of teachers who made comments relevant to this table; Y is the total number of teachers who responded to the *Elaborate* phase.
**
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. L6 (Investigating water use at home) and L7 (Water in other places) are reported here.

Unit	Concept(s)	Concepts in New contexts (X/Y)*	Comments
Water works S1**	Uses of water	6 (+3)/11	Six teachers (4, 8, 10, 11, 12, 15) focused on uses of water in new contexts, while others (3, 6, 8) implied it
On the move ES1	Effect of surface on movement (push and pull)	6/8	All teachers referred to fair testing, with six mentioning moving objects and/or how they moved, e.g., roll or slide (10) and tumble (8)
Earth's place in space S3	Movement/ properties of planets and their moons (compared to Earth)	4/13	Teachers applied 'Earth/Moon' ideas to solar system (4,8,14,15)
What's it made of? ES1	Properties of objects/materials affect their use	3 (+2)/12	Three teachers (3, 5, 11) clearly referred to application of the concept (e.g., materials in playground: 5). Two others (7, 8) implied: sorted and found items for sculptures (8)
Electric circuits S3	Electric circuit	3/11	9/11 teachers, despite some 'connection' issues, indicated how much the activity was enjoyed; only three clearly referred to concepts
Staying alive ES1	Water needs (consumption) of animals	5/8	Choice of pet discouraged four teachers from completing, while two varied (to guinea pig or student intake of water)
Schoolyard zoo S1	Needs of living things	2/5	Reference made to comparing habitats (1) and animals in different environments (4)
All sorts of stuff S2	Materials have a range of properties	2/10	Two teachers directly referred to absorbency (6, 9), while seven others referred to aspects of fair testing (2, 4, 9, 14, 15, 19, 21)
Material matters S1	Solids, liquids and gases: their nature and properties	2 (+1)/8	Probable application of ideas testing for suitability for raincoats and umbrellas (5, 7); a general comment suggested application of ideas to lunches (11G)
Spinning in space S2	Shadows relate to Earth spinning on axis	1 (+2)/9	Eleven teachers (1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 14, 18) indicated shadow stick records were kept by students, with possibly three relating to testing predictions, but probably not earth spinning

Weather in my world ES1	Impact of weather on people (e.g., choice of clothes)	1 (+1)/7	Used teddies with different outfits (7); students found difficult to recall clothes people wear (7) or with jobs (8)
Change detectives S***	Physical & chemical change: dissolution and rate of reaction	2/8	Seven teachers commented on fair testing****, with two (9,10) mentioning variables that may affect rate of reaction; one strongly implied change: 'Fitting together the reasons why tablets fizz and the fact they actually are doing a job was like watching light bulbs go off' (9)
Push-pull S1	Forces: direction and magnitude	1 (+1)/6	All six classes fair tested helicopters (forces in a different context), but only one comment referred to forces (4). Suggestion that students correctly labelled diagrams (1)
Smooth moves S2	Forces: direction and magnitude	1/8	Two teachers thought the ideas too complex, while seven referred only to fair testing with no mention of the force concept; of these seven three added the fair test goals were met, while all seven identified fair test difficulties
Plants in action S2	Plants: life cycle; conditions for growth	1 (or 5)+/9	+If investigations are interpreted to be applying ideas about the conditions for growth of plants, then 5/8
Marvellous micro-organisms S3	Micro-organisms: role; conditions for growth	1 (or 10)++/16	++If fair testing is interpreted to be applying ideas about the conditions for growth of micro-organisms, then 10/16

*** The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of *Change detectives* S3. Lesson 6 in the draft version is the basis for the data reported here.

**** Some comments could be interpreted as teachers assisting students to extend their understanding of fair testing to new contexts rather than physical and chemical change.

5.41 Use and apply concepts and explanations in new contexts to test their general applicability

Table 5.6 suggests that using and applying concepts and explanations (mentally 'organised' by students in the *Explain* phase) in new contexts to test their generalisability was not explicit in many teachers' comments across several units. If comments that implied this purpose are also considered, there were still units that may have rarely mentioned the use and application of ideas in new contexts, such as WW, ASS, SZ and SM (*see* Table 5.6). As outlined later in this section, teachers (at times) may have been more focused on students successfully carrying out fair tests, that they did not mention how the tests related to the conceptual purpose of the unit.

Teachers' comments clearly indicated that students completed a range of investigations in the *Elaborate* phase, but as Table 5.6 shows, the numbers that suggested students' attention was drawn to the application or extension of key science concepts were usually limited. There was not necessarily a connection between teachers referring to these key concepts in the *Explain* phase and then revisiting them (in their comments) in the *Elaborate* phase. This is apparent as, for example, understanding of *electric circuits* was clearly mentioned in the EC *Explain* phase (8Ts) but its application/extension by fewer (3Ts); ASS is similar (8 explain/ 2 elaborate), while OTM is the opposite (1T/6T). Teachers probably commented on what caught their attention about activities in the *Elaborate* phase and, except for a minority, this 'conceptual' purpose was not uppermost in their thinking. There is also the possibility that some teachers may have been unclear about the intention of this purpose and, hence, did not focus on how the *Elaborate* tasks may have been using and/or applying the units' main idea(s). These main ideas are listed in Table 5.6 and, on occasions, the connection may not have been explicit, as in an investigation of shadows and its relationship to the rotation of the Earth.

As mentioned above, fair testing was a major focus in most units. Table 5.6 also records how often teachers mentioned fair testing (but usually without referring to science concepts or understandings [SU]): examples include ASS (7Ts fair testing/ 2Ts SU); CD (7/2); PP (6/1); SM (7/1), but there were exceptions, namely, OTM (8/6) and possibly MM (1 or 10/10). In some units, teachers' comments clearly indicated students were further developing their understanding of fair testing (also a Primary Connections goal), even if the focus was not on SU.

Contexts in which concepts were tested or expanded

Most teachers included comments that indicated or suggested the contexts they were using. These were sometimes described in the Primary Connections units, but at times it was clear teachers had taken other initiatives. Some of these are summarised in Table 5.6 (e.g., *see* MMat). Other illuminating examples were:

- *Application of force ideas to movement*: OTM was a unit where most teachers combined comments about investigations with the underlying 5E concept(s), as in: 'Took things outside and tested on slide (roll, slide, tumble), students traced objects onto large piece of paper and labelled how the item moves—some wrote, some drew' (T8); 'Interesting concepts came up, such as children predicting one container would roll in a circle because the top was wider than the bottom; Children then wanted to test other round items' (T1); 'LS10—using 2 hoops, made equivalent of Venn Diagram on floor and organised the objects tested (roll; slide)' (T10 OTM). In the two subsequent units, PP and SM, this, in general, did not occur, although a teacher did say: 'It was good to apply tests and understandings to different situations' (T1, PP);
- *Investigating water, its sources and other aspects (Ww):* Five comments, including: 'Went on excursion to Cotter dam and followed the path of water supply, kids loved this excursion' (T8); 'Had several guests into class, Gutter Guardians project, Water Watch and street sweeper from local council'(T11); 'We made an oral language game where children picked up "occupation" cards (teacher, doctor, farmer, fireman etc.) and the ways that these people used water' (T12);
- *Applying a knowledge of properties of materials in deciding their use:* In WM, three comments implied concepts were used in new situations, including:

> We put out items that were not suitable as an evaluation task and this created a lot of discussion about suitable materials between classmates and the whole class. (T11)
> Session 2, Step 1 Talked about raincoats and things we wear in the rain…. Didn't complete sculptures (as in Primary Connections) but will be making signs for our bike track outside. Children will need to consider materials. This conceptualises our work and gives an authentic reason to make something for outside. (T3);

- This last mentioned response not only indicates that the teacher appreciates the task ('conceptualises our work'), but also that an 'authentic' context has been selected. This teacher added later: 'Session 2, Step 1 Talked about raincoats and things we wear in the rain', again suggesting application of the focus concept in this sequence;
- *Applying the concepts of physical and chemical change* were not readily apparent in CD, but one teacher clearly indicated how their students investigated how variables affect the rate of reaction of materials and substances, i.e., extending the key concept. Learning was obvious, but whether the teacher encouraged thinking about variables and chemical change is not known, but may be implied in 'the way the tablets work':

> All the students talked about having taken 'fizzy medicines' and so this experience was common to all. Fitting together the reasons why tablets fizz and the fact they actually are doing a job was like watching light bulbs go off. It was very rewarding for *me*! … The actual work on tablets and the variables was great although we spent a lot of time discussing it, lots of questions and answers, lots of 'What do you think …?' etc. The *children* (I think) are grasping how the differences in tablets' size/shape/broken/exposed/hard etc. affect the way the tablets work and how well they work. (T9)[47];

- *Applying the concept of an electric circuit to the identification of conductors and insulators and/or the use of switches:* In EC all 11 teachers appeared to engage students with the activities related to conductors and insulators, but it was not obvious that they saw this as application of an idea to a new context. An example of a teacher who appeared to appreciate this purpose was (for insulators and conductors): 'Children looked for common aspects amongst the materials, through which electricity passed and common aspects of materials/objects through which electricity did not pass' (17 L6 circuits);
- *Relating water consumption to an animal's needs:* This was an example where very young learners, with teacher assistance, completed a 'test'. In some instances, it was strongly implied that the concept was discussed after a fair test. Using a guinea pig, the amount of water drunk by some children, the teacher and the guinea pig was observed, a graph made and findings discussed.

More a focus on fair testing than its use in applying conceptual understanding

Thinking and working scientifically has been conceptualised by Feasey (2012), in which both are integrated. To answer a scientific question or solve a problem students need to bring together their understanding of science concepts, their knowledge of and ability to apply skills, and an understanding

'All the students talked about having taken "fizzy medicines" and so this experience was common to all. Fitting together the reasons why tablets fizz and the fact they actually are doing a job was like watching light bulbs go off. It was very rewarding for me!'

47 Of interest is that this teacher (9 CD), who most clearly indicated that the concept was being applied in a new context, also used a range of modes (although there was difficulty with graphing).

of and ability to apply (concepts of) evidence (Feasey, 2012, p. 65) and, as has been emphasised for many years, science learning is less effective if process and conceptual understandings are not taught together (Miller & Driver, 1987). In the *Elaborate* phase teachers, at times, commented how they were focusing on aspects of fair testing, such as controlling variables, but not mentioning in their comments any contextual content, such as the underpinning concepts that the fair testing was focusing on; examples included: 'Reinforced fair testing as some groups did not keep tests consistent' (T10 ASS) and used 'Variables grid and each student group selecting one variable to investigate.' (T5 CD)

Several comments also indicated how students were progressing in their use of fair testing. In CD, five teachers (CD 1, 3, 6. 8, 9) commented on how well the fair testing had progressed, and it was also implied in ten MM teachers' comments, with some of them referring to how students had become independent in their fair testing investigations (T3), selected their own variables for testing (T17), tested their predictions with 'parallel experiments' (T19)—however, these teachers did not refer to concepts about micro-organisms[48].

As indicated in Table 5.6, many CD teachers referred to fair testing, and one teacher was explicit that their students were *applying a fair test* (not necessarily physical and chemical change concepts) *in a new situation*:

> We used Panadol and Berocca tablets again and the students recorded the time taken both with hot and cold water. They worked out, in groups, how they were going to do this one *but they had an idea from the previous time*. (T10 CD italics added)

Sometimes reports about fair testing were not positive. In SM, for example, the purpose was to use a fair test to apply ideas about forces. Three teachers (4,6,11) said their class achieved this goal for the fair testing, but others focused mainly on whether the students could understand and/or complete the fair test, with none referring to ideas about the force concept. They referred to a range of distracting factors: equipment issues (Ts 10, 3, 6) including inability to keep variables the same for students (T7); the concept was too difficult for students (Ts 3, 5); students had difficulty recording (T4) and graphing (Ts 6,11); the teacher felt it was an inappropriate task (i.e., catapult) (T4); the teacher had difficulty with the variables grid (T7); and some teachers felt students did not understand variables (T5) and fair testing (Ts 5, 10).

Two vignettes: application of concept in new contexts

Earth's place in space S3

An issue that surfaced from teacher feedback in this phase was whether the teachers recognised the concept(s) that were being applied in new contexts and/or whether the unit made it clear what were the concept(s) to be applied in new contexts:

> It seems that everything up to the *Elaborate* phase focused on the Earth, Moon and Sun and incorrect vs correct theories, then, POW, all of a sudden we have the whole solar system to grapple with. (T9)

In the following extracts, it is inferred that teachers considered that the other planets (and their moon(s)) behaved similarly to the Earth (and its Moon) in terms

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As indicated in Table 5.6 if a key concept in this unit was extending ideas about the conditions for growth of micro-organisms, then it could be implied that these ten teachers were relating learning to that concept as in: 'Had different degrees of light, moisture, temperature and composition of bread and children selected their own variables to investigate' (22 MM).

of their movement, and that this was the science idea (including notions of 'orbit', 'rotation' etc.) to be applied in new context:

> They are starting to get concepts of Earth Days and Earth Years, especially since working with models (that included other planets). (T8, parentheses added)
>
> Really enjoyed researching/recording/applying information about planets (solar system) to build models. (T5)
>
> I changed this section somewhat as had no time for research or for children to convert measurements to scale. Instead I gave them information and, in groups, they used compasses for first time and put their planets on a chart. They particularly enjoyed seeing just how much bigger the sun is. (T15)

Spinning in Space S2

This phase was the focus of Lesson 5 (and included two sessions). Although 14 teachers made comments about this phase, there was only minimal feedback that directly focused on the two purposes of the *Elaborate* phase. One teacher (T7) clearly intimated that students tested ideas (related to the 'new' context of shadow investigations): 'did activity as a whole class with enlarged Investigator planner, told them what they were going to investigate, wrote individual hypothesis.' (T7)

Although here the teacher identified the investigation task, it was the students who offered a range of hypotheses (which would then have been tested). However, it is not clear whether these were predictions (e.g., where the shadow will be next) or hypotheses (e.g., the shadow will be … because the Earth will have spun a long way on its axis).

Other teachers clearly indicated that their students were investigating problems about shadows. However, it is not clear if the question on the 'Investigation planner', namely, 'Can you explain the relationships, patterns or trends in your results? Try to use some science ideas to help explain what happened' (Trial unit, Resource Sheet 3, p. 3) was a focus after data had been collected (i.e., applying the unit's idea to a new context). The following does suggest that this may have been the case for two teachers (T2 'predicting, discussing' and T6 'investigation evidence was excellent' (T6):

> Fantastic activity, shadow stick, with children recording, predicting, discussing (T2). Data chart worked well (T2).
>
> Experiment great. The children loved having to move every hour to record their results (T3).
>
> Used digital photos for retell of shadow stick activity. Hand drawn graphs and Excel used (T5).
>
> Terrific activity. Investigation evidence was excellent …. Graph was a great assessment tool (T6).

The above must be problematic, as one teacher's (T21) comments may suggest that the Sun is moving (rather than the apparent movement of the Sun is a result of the Earth spinning):

> This lesson should be done after Lesson 3 as they both ask *children* to show the sun's movement recording and lengthening shadows. (T21)

As direct evidence is not apparent, then it remains problematic as to whether these teachers recognised the concept(s) that were being applied in new contexts. The lesson outcomes for the *Elaborate* phase do not explicitly state the central concept being applied.

5.42
Reconstruct and extend explanations and understanding using and integrating different modes

This second purpose, using various modes to reconstruct and extend understanding developed in the *Explain* phase, was mentioned in most units across all strands. Teachers mentioned using linguistic (verbal, written), kinaesthetic mathematical (graphical, measurement, tabular) and visual (pictorial, diagrammatic, tabular[49]) modes. Furthermore, on many occasions, it was reported that several modes were used and/or integrated. The manner in which these modes were used is shown in the example extracts and/or the comments summarised in Appendix 5.5. It also suggests that several teachers in each unit used a variety of modes, but this was less common in WW and MMat; these were two units when some teachers indicated there were learning difficulties for their students, such as inability to express ideas about the topic because of a lack of adequate language. It poses the question, would the use of different modes have helped?

Examples of how some of these modes were used and/or integrated to extend understanding and explanations included: ‘Students completed large graph, then created individual graph, discussion was interesting as children did not know a lot about saving water, so had an extra lesson on this topic’ (T11, L6 Ww); ‘coloured individual photos enhanced students’ presentation’ (T6 ASS); ‘Used photos to show fair test … students created graph using A3 paper, record[ing] distance rolled with strips of crepe paper’ (T5 OTM); ‘Optional role-play was great to give the students an idea of what was required. I used the role-play and various concept cartoons as stimuli to assist students in their investigations of switches in circuits’ (T13 EC L8); ‘Some students were excellent speakers and found the presentation interesting and challenging, good experience for less literate children to prepare speech and present to class’ (T2 MM L7); ‘We simply reviewed our previously covered criteria for scientific drawing and applied them to drawing a flower’ (T13 PA L8); and:

> Children used tally mark on cup if filled again during the day. We made a human graph by children standing in columns depending on no. of cups of water drunk during day. We discussed and children observed and commented. We said sentences e.g. Six children had four cups of water (8 SA *Elab*)

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Tabular is listed in two places, as they were numerical and qualitative.

5.5 *Evaluate* phase

Two purposes are to be addressed in this phase. These are:

- Provide an opportunity for students to review and reflect on their learning and new understanding and skills.
- Provide evidence for changes to students’ understanding, beliefs and skills.

The *Evaluate* phase always involved one lesson. Appendices 5.1 and 5.2 overview the range of responses for the two purposes. Teachers' comments indicate that the first purpose was addressed by most teachers across most units and at least by some teachers in all units. As will be outlined below, there was strong evidence for (teachers and) students reviewing their conceptual understanding (but not their skills), but it was less common to read that teachers had provided opportunities for students to reflect on their learning (as in the learning processes used) and their understanding and skills. A distinction has been drawn here between reviewing and reflecting, as implied in the purpose statement. The second purpose, in general, was the focus of far fewer teachers' comments and was not mentioned in four units (WM, MMat, WW and EP). This latter purpose required teachers' comments to include some reference to 'changes' in students' learning. In this final 5E phase the focus is on summative assessment (also *see* Chapter 9).

It will be noticed from appendices 5.1 and 5.2 that the response rates for the *Evaluate* phase is far less than the other phases (for most units) (also *see* Table 3.2). In several instances, teachers said they did not complete the *Evaluate* phase; however, the generally low response rate does suggest that quite a few more teachers did not implement this phase. As this appears to have been the case, then these teachers only have their formative assessment observations (and possibly notations) to determine the success of the unit. As outlined, 'success' here covers a range of factors, such as movement in SU, SIS and student feelings about science and their science learning.

5.51
Provide an opportunity for students to review and reflect on their learning, new understandings and skills

The three elements of this purpose are separated in Table 5.7. It clearly indicates that in 10 units, two thirds or more of teacher comments (102 in total) referred to reviewing SU, with EP the only unit with less than a quarter of responses. In contrast to this focus, only 10 teachers (across four units) mentioned reviewing SIS[50]. About twenty teachers encouraged students to reflect upon their learning in the unit, including learning processes and their feelings about the unit.

Assessment processes used with examples

Teachers referred to a wide range of review strategies apart from the more common discussion, straight-forward written responses and quizzes. As shown in Table 5.7, these included novel approaches, such as a 'newspaper' (Ww), a design task (ASS, EC), grouping using hoops (OTM), thinking hats (SM), an electric circuit problem (EC), interactive crossword (MM) and creating an invertebrate (SZ). Some teachers also referred to using student journals for this purpose (PP and MM). Several of these met with enthusiastic comments from teachers (e.g., plant-life jumble [T21 PA]; 'What am I' activity (T11 MMat). Extracts exemplifying some of these more novel approaches include:

> Children were asked to create their own invertebrate and consider its environment/ habitat. They had to consider movement, defence, environment and write a report to demonstrate how animals' features assist it in living in its environment. (T6 SZ)

Used interactive whiteboard to adapt the information wheel and added small pictures representing the senses. Each student had a piece of apple to eat. This helped. (T5 SA L7)

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The *Evaluate* purpose refers to 'skills' but the Primary Connections units indicate that teachers are to summatively assess skills in the *Elaborate* phase. This probably explains why teachers did not explicitly refer to skills in the *Evaluate* phase.

Table 5.7: Teachers who provided an opportunity for students to review and reflect on their learning and new understanding (and skills)*

*
Some teachers did still refer to SIS in the *Evaluate* phase:
a) EP—2 teachers (discussion re use of evidence NoS 11; better scientists NoS 13)
b) EC—2 teachers (word loop and solve circuit problem NoS 13)
c) CD—1 teacher possibly implied NoS in mess scene 4.

**
This is the total number of teachers who responded to the *Evaluate* phase item on the feedback pro forma; not all of them referred to the content of columns 3 and 4.

Unit	Teachers**	Students review understandings (including some examples)	Students reflect on their own learning (including examples)
Electric circuits S3	9	8 (Discussion1,3, word loop 6, 15, 8 (implied) word loop + Solve circuit problem 11, written descriptions + check circuits with galvanometer 19,8, design task 13)	4 (+3) (Journal 2; Resource sheet- affective responses 6,1,15 (implied) 12, 18, 19)
Water works S1	11	6 (Map 12; 'newspaper' 1, 5, 8, 11; quiz 1)	0
Spinning in space S2	11	5 (Mind map 1, 2, 18, 19; RS1 (18); PowerPoint, digital photos, move 5)	0
All sorts of stuff S2	8	5 (Written task 8; design 10, 18; spider web 6; discussion 14)	1 (Views about learning 14)
Smooth moves S2	6	5 (Presentations—as on TV 1,5; reviewed PowerPoint + thinking hats 6 + as in PC 11, 5)	1 (Thinking hats 6)
Schoolyard zoo	5	5 (Leaf litter task 4,7,9; create own invertebrate + written report 6; large class mural 6)	(1) (4)
Plants in action	7	5 (Interactive crossword 1; TWLH (3); life-cycle jumble 3, 21; write-up (6); portfolio piece 12)	2 (7,10)
Marvellous micro-organisms	4	4 (Quiz 3; class summary 18; implied presentation 24; science journal 7)	1 (2)
Change detectives S3	4	4 (Mini-report 3; presentation: oral, PowerPoint, Kahootz, posters 6 (only oral 10: discussion 8)	3 (3G, 10G)
On the move ES1	6	4 (Modelled grouping using hoops 5; students acted out words 7; changed RS4 uk; unstated tasks from LS4 3)	0

Earth's place in space S3	13	3 (Discussion 9, 13 test/revision sheet 11)	1 (What students liked 11)
Material matters S1	5	3 (Shared book 2; What am I? 11; matching task 9)	0
What's it made of? ES1	5	2 (Discussion 1,uk)	1 (1)
Push-pull S1	7	3 (Discussion/questioning 3, 4; videoed verbal explanations + journal 5)	(1) (4 may have implied)
Staying alive	3	3 (Tree diagram 7; oral presentation 4, information wheel 5)	2 (5,7)
Weather in my world ES1	3	2 (Letter 4, discussion 11)	0

> Wanted students to make different models using circuits to allow more creative problem solving .... Children to decide on purpose of model, drawing of plans, create group plan, decide on materials needed and who can supply, make model, prepare talk to include information on how each component works, why certain materials were used, how energy is transferred or transformed .... (T11 EC)
>
> Created an informal fun newspaper as it was the end of term .... Gave teams a large sheet of newsprint onto which children drew water statements, maps, ads, assembled sheets as 'The Daily Sprinkle' (T5 Ww; another (T11) referred to a computer application for developing a newsletter).

Assessing science outcomes: some illuminating issues

Assessing SIS.

As outlined above, very few teachers' comments suggested that inquiry skills were being assessed. The instances noted in Table 5.7 are built into tasks that also assessed SU (as in the design task or the circuit problem described below). Although skills are stated within the purpose statement for the *Evaluate* phase (AAS, 2008a, 5Es resource sheet 3:2), it is noted that in the Primary Connections curriculum units published prior to that time it is the *Elaborate* phase where summative assessment of 'investigating' outcomes is located (e.g., MM, most recently revised 2006). This may account for the absence of this component of the purpose in the teachers' *Evaluate* phase comments.

The frequency with which teachers mentioned inquiry skills is shown in Table 7.1, and the references to fair testing in the *Elaborate* phase are summarised in Table 5.6. This latter table shows that students were using quite a variety of skills, but references to teachers 'assessing' them in a summative sense was not discerned.

Varied assessment processes in the same Evaluate phase are sometimes required.

One teacher indicated that assessing understanding sometimes required variations in assessment processes:

> I found that often children needed to be individually questioned to get an accurate picture of their understandings. Some couldn't demonstrate their understanding in diagrams but could answer questions orally. (T3 PP L9)

Authentic assessments, if possible, are preferred.

Another teacher believed the assessment needed to be more authentic. This teacher created a context for the task (while two others [Ts 8, 12 ASS] implied this was required): 'Used World Environment Day topic of Rainforests as topic for which children were asked to design a home and clothing, what materials you would use and why (18). This does suggest that Primary Connections reminds teachers to place assessment within a suitable context (and this was done in the revised Primary Connections unit, p. 58).

There is a need to distinguish knowledge from understanding.

One teacher commented: 'Didn't really test all the general knowledge of the students, to give you an overall grade for the students, had to design my own test/ revision sheet'. This teacher was referring to 'knowledge', while the following teacher distinguished 'facts' from 'concepts', which is the focus of the 5E schema: '... kids really struggled with the idea of not just giving a fact instead of explaining a concept' (T13).

Nature of science outcomes can be assessed.

One teacher (T11 EP) also implied that NoS outcomes may have been (inadvertently) assessed—see the reference to 'arguing'—(albeit having difficulty doing so): 'Children had difficulty arguing the point of view that the earth was the centre as they really did not have enough background knowledge'. Another response suggested more NoS success: 'A nice piece of symmetry to revise the start and finish with the students showing if they were scientists' (T13 EP).

Quality and novel assessment can take time that teachers may not have.

Novel assessment (e.g., student dialogue in a play, which in EP was meant to determine students' ability to use evidence etc.) takes time, and this was an issue for at least one teacher: 'It was decided to create a different assessment format, as again, because of time restraints—creating dialogues/plays/cartoons are all very time consuming' (T15).

Examples of students reflecting on their learning

Teachers encouraged this in a variety of ways. They had students 'write reflections (in their science project book) in work after each session' (T2G MM); 'Did the reflection in a separate follow up lesson in literacy as this lesson was too full' (T5 SA L7); 'Fantastic (reflection resource) sheet—out of 80 students, 1 child said he did not like science (hates school), 3 said they loved it but felt they did not do well and 90% said they love it but would like more hands-on'(T15 EC);

'... Then children sat in small groups and reflected on the unit using the Thinking Hats' (T6 SM); 'Students were able to relate well to what they like and reflect that in their responses. They loved learning about the planets' (T11 EP); and:

> The kids wrote some wonderful reflections about the unit. Most thoroughly enjoyed learning about change. They loved the experiments .... We used the sample questions from question 6 to write a reflection/ mini report about what we had learnt about change .... Our curriculum was too crowded for a report project so we spent our last hour of this unit reflecting on our experiences and acquired knowledge (T3 CD).

'The kids wrote some wonderful reflections about the unit. Most thoroughly enjoyed learning about change.'

5.52
Provide evidence for changes to student understanding, beliefs and skills

From Table 5.8, it is noted that fewer teachers commented they had collected evidence of changes in student understanding, beliefs and skills[51]. With reference to SU, some teachers made reference to this purpose, except in the units WW and WM. More teachers commented on changes in the 'Energy and change' (SM and EC) and the 'Earth and beyond strands' (SS, EP), but overall, there did not appear to be any connections between strands and teachers' comments on changes to SU.

Several teachers' comments referred to being able to 'gauge individual progress in learning' (T19 EC), 'see where students were at in their learning' and that students were 'consolidating their learning' (T4 SZ; T3 EC). At times, teachers included reference to the conceptual area in which change was noted. Examples included students learning 'so much about air and moving things' (SM T4) and what they 'had learnt about change' (T3G CD).

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Skills will not be discussed in this section for the reasons previously outlined.

Two observations about evidence of changes in students' learning

Persisting with Evaluation focus

An instructive comment was made by a teacher who clearly knew what they were looking for in students' assessment tasks. It emphasises that teachers need to be clear about the conceptual foci they are assessing:

> I had to keep sending the kids back to their desks to include more information and kept pointing to our word wall. *Many of the students did not include friction* and could not identify correctly where it would be (T5 SM emphasis added).

Longer-term learning

Some teachers did indicate the overall impact that Primary Connections can have on students' learning. One referred to the longer-term learning that appeared to have occurred:

Had to carry this session into Term 2. Students surprised teacher with the amount of information they had retained. All understood what the cycle represented. (6PA)

Table 5.8: Teachers who provided evidence for changes to students' understandings*, beliefs and skills**

* When teachers referred to 'knowledge' or similar, this was interpreted as 'understandings'.

** Exemplar extracts within text to support these data.

*** This is the total number of teachers who referred to this item on the feedback pro forma; not all teachers made reference to the content of columns 3 and 4.

**** Knowledge is implied in the 'skill' components referred to here (e.g., use of evidence in an argument).

Unit	Teachers (who responded to *Evaluate* item)***	Evidence for changes to understandings	Evidence for changes to skills
Weather in my world ES1	3	0	0
Water works S1	11	2 (12, 1)	0
Spinning in space S2	6	4 (1,2,18, 19)	0
Earth's place in space S3	13	(2)**** (9,13)	2 (9,13)
What's it made of? ES1	5	0	0
Material matters S1	5	1 (From an earlier teacher unit 'Transport')	0
All sorts of stuff S2	8	1 (+2) (10; two other implied 1, 14)	0
Change detectives S3	4	2 (3,9)	0
On the move ES1	6	1 (10 retained more than teacher thought)	0
Push-pull S1	7	1 (4)	0
Smooth moves S2	6	4 (4,5, 6, 11)	0
Electric circuits S3	9	4 (3,12,15,19)	0
Staying alive	3	1 (7)	0
Schoolyard zoo	5	(1) (4 consolidated their learning)	0
Plants in action	7	4 (3,6,12,21)	0
Marvellous micro-organisms	4	2 (5,7)	0

Elsewhere in this report are other comments that indicate that students who have studied two sequential Primary Connections units on the same conceptual area have retained some understandings from the pre-requisite unit (*see* section 4.26).

Vignette: complexities of obtaining conceptual change

An EP teacher commented: 'Did not resolve issues regarding day/night, orbits of planets and moons, concept of weather and climate' (T10). This suggests that even the basic idea of day and night was problematic in this class. A search locating this teacher's comments found that they referred to their students enjoying the concept cartoon, finding RS4 'confusing', 'enjoying' some aspects of the *Explore* phase; and 'used tables and discussed (provided and found) data in the *Elaborate* phase, although her students had difficulty with 'scale'. This teacher added that they 'did not address any misconceptions in the first three lessons' and also thought there was 'too much time focusing on misconceptions. Need more direct teaching of concepts thinking'.

From this teacher's comments and thoughts it would appear that a plausible interpretation would be that more scaffolding of student thinking was required in the earlier phases, and the *Explain* phase did not narrow down student thinking on the key concept(s). However, it does need to be borne in mind that despite quality teaching using constructivist strategies, there is ample research evidence indicating how difficult it can be for some students to re-construct their existing ideas (Skamp, 2012a,d), and astral concepts can fall into that category (Brewer, 2008).

5.6 Addressing 5E purposes across the four content strands and primary levels

Tables 5.9A and 5.9B are based on the responses in appendices 5.1 and 5.2. They overview the minimal levels of response to each of the 5E phases across the four content strands and the four primary levels. These levels are minimal, as more teachers may have addressed these purposes but not mentioned them. The levels are indicative of the responses across the majority of units within a strand. If two or more units had 75% or more responses that referred to a particular phase purpose then the addressing of this purpose was rated 'very high'; 50% was 'high'; 25% 'moderate' and otherwise 'low'. The sample sizes varied from eight (SA) to 18 (MM), while the range of frequency of responses varied from zero (in seven units for 'raise questions for inquiry') to 9/9 (for 'create interest and stimulate curiosity' in CD). In summary, the detailed analyses of the 5E purposes in this chapter indicate that:

- some purposes in each phase are addressed very well across all strands and primary levels (e.g., creating interest in the *Engage* phase, providing experience of the phenomenon or concept in the *Explore* phase, using conceptual tools in the *Explain* phase, using a variety of modes in the *Elaborate* phase, and students reviewing their understanding in the *Evaluate* phase); and
- some purposes may not be addressed by many teachers across all strands and primary levels (e.g., raising questions for inquiry in the *Engage* phase and students comparing their own explanations in the *Explain* phase).

Otherwise, there are mixed findings, with several purposes in the moderate to high range across strands and year levels.

Table 5.9A: Minimum levels of responses* that explicitly addressed the purposes of the 5E phases across four units in each of the four content strands

* These levels are minimum levels, as more teachers may have addressed these purposes but not mentioned them. The levels are indicative of the responses across four units at the same primary school level/stage. If two or more units at a particular level/stage had 75% or more responses for a particular purpose, then addressing that purpose was rated very high; 50% high; 25% moderate and otherwise low. The sample sizes varied from eight (SA) to 18 (MM), while the frequency of responses varied from zero (in seven units for raise questions for inquiry) to 9/9 (for CD). For details, *see* Appendix 5.1.

Purpose	Life and living	Energy and change	Natural and processed materials	Earth and beyond
***Engage* phase**				
Create interest and stimulate curiosity	Very high	Very high	Very high	High
Set learning within a meaningful context	High	Low	Low	Low
Raise questions for inquiry	Low	Low	Low	Low
Reveal students' ideas and beliefs, compare students' ideas	High	Moderate	Moderate	Moderate
***Explore* phase**				
Provide experience of the phenomenon or concept	Very high	Very high	Very high	Very high
Explore and inquire into students' questions and test their ideas	Moderate	Moderate	Low	Low
Investigate and solve problems	High	High	Moderate	Moderate
***Explain* phase**				
Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	Very high	High	High	High
Construct multi-modal explanations and justify claims in terms of the evidence gathered	Moderate	Low	High	High
Compare explanations generated by different students/groups	Low	Low	Moderate	Low
Consider current scientific explanations	Moderate	High	Moderate	Moderate
***Elaborate* phase**				
Use and apply concepts and explanations in new contexts to test their general applicability	Moderate	Moderate	Moderate	Low
Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	Very high	High	Moderate	High
***Evaluate* phase**				
Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	Very high	High	High	Very high
Provide evidence for changes to students' understanding, beliefs and skills	Very high	Moderate	Moderate	Low

Table 5.9B: Minimum levels of responses* that explicitly addressed the purposes of the 5E phases across four units in each of four levels of primary schooling

	Early stage 1	Stage 1	Stage 2	Stage 3
***Engage* phase**				
Create interest and stimulate curiosity	High	Very High	Very high	Very high
Set learning within a meaningful context	Low	Low	Low	Low
Raise questions for inquiry	Low	Low	Low	Low
Reveal students' ideas and beliefs, compare students' ideas	Moderate	Moderate	High	Moderate
***Explore* phase**				
Provide experience of the phenomenon or concept	Very High	Very High	Very High	Very High
Explore and inquire into students' questions and test their ideas	Moderate	Moderate	Moderate	Moderate
Investigate and solve problems	Moderate	High	Moderate	Very High
***Explain* phase**				
Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	High	High	High	Very High
Construct multi-modal explanations and justify claims in terms of the evidence gathered	High	Moderate	High	High
Compare explanations generated by different students/groups	Low	Low	Low	Low
Consider current scientific explanations	Moderate	High	High	Moderate
***Elaborate* phase**				
Use and apply concepts and explanations in new contexts to test their general applicability	High	Moderate	Low	Moderate
Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	High	Very High	High	High
***Evaluate* phase**				
Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	Very High	High	Very High	Very High
Provide evidence for changes to students' understanding, beliefs and skills	Moderate	Low	Moderate	High

* These levels are minimum levels, since more teachers may have addressed these purposes but not mentioned them. The levels are indicative of the responses across four units at the same primary school level/stage. If two or more units at a particular level/stage had 75% or more responses for a particular purpose, then addressing that purpose was rated very high; 50% high; 25% moderate and otherwise low. The sample sizes varied from eight (SA ES1) to 18 (MM S3), while the frequency of responses varied from zero (in seven units for 'raise questions for inquiry') to 9/9 (for 'create interest and stimulate curiosity' in CD S3). For details *see* Appendix 5.1.

There do not appear to be any consistent trends across stands and year ranges. A *very* speculative look at the table might suggest that:

- Life and Living units tended to address engage purposes more than other strands;
- Life and Living, and Energy and Change units tended to address *Explore*, *Elaborate* and *Evaluate* purposes more than other strands;
- Natural and Processed Materials, and Earth and Beyond tended to address *Explain* purposes more than other strands; and
- upper primary students (S3) tended to address *Explore* and *Evaluate* purposes more than other levels.

As stated, these are proffered more for reflection than in any sense being definitive (due to the nature of the data and the analyses). If they resonate with Primary Connections leaders, then there may be reason to reflect further on the strands and levels and details within Chapter 5.

5.7 Implications for the implementation of Primary Connections and the 5E phases

A summary of the findings and insights from the separate 5E phases is in Chapter 12 (section 12.5). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

PC FINDINGS

The units encouraged investigative science and occasionally autonomous student learning.

Chapter 6

A constructivism lens on Primary Connections

6.1 Constructivism, Primary Connections and the 5E model

> *Primary connections* is based on an *inquiry and investigative approach* in which students work from questions through investigations to constructing explanations and is therefore consistent with *contemporary constructivist learning theory*. Students are given the opportunity to *represent and re-represent their developing understandings* using a wide range of texts and information and communication technologies (ICTs). *Assessment is integral* with teaching and learning. Students' representations of their developing understandings provide opportunities for *teachers to monitor students' learning progress and use this information to facilitated further learning*.
>
> (Hackling & Prain, 2005, p. 8, italics added)

Primary Connections is underpinned by an approach based on *constructivist learning theory*, in which is embedded an *inquiry-oriented and investigative approach*. Learning is, in part, developed *through language* ('Students … represent and re-represent their developing understandings using a wide range of texts …'). Assessment, particularly formative assessment ('… teachers to monitor students' learning progress and use this information to facilitate further learning'), *is embedded* in the initiative. These four areas—constructivism, inquiry, language (especially 'talk') and formative assessment—have been argued by Harlen (2009) to be the basis of an emerging, and more effective, pedagogy in science. In this project, these four areas will become lenses through which teachers' comments about implementing Primary Connections trial units will be further analysed. There is some overlap between Harlen's lens and the detailed 5E analyses of chapters 4 and 5, as well as the later analyses in this report, which ask if teachers' feedback comments also address a range of conditions for effective learning derived from the Science in Schools (SiS) project (Tytler, 2003). Consequently, reference will be made in these various chapters where overlap occurs.

6.2 The 5E model through Harlen's constructivist lens

> Constructivist pedagogy starts from [students' existing] ideas and sees the role of the teacher as providing children with experiences, evidence, and reasoning skills that will enable them to construct *scientific* ideas. (Harlen 2009, p. 36)

This view of constructivism is founded on a very wide research base (e.g., *see* Vosniadou, 2008), and embraces both personal and socio-cultural constructivist perspectives (*see* e.g., Skamp 2012a), with the latter more strongly emphasising the role of communication and language in the way learning occurs. A pedagogy that acknowledges these perspectives in a constructivist theory of learning will encourage the following learner roles (Harlen, p. 40):

- learning actively (mentally and physically);
- discussing own and others' ideas;
- using ideas to try to understand new events/phenomena;
- reasoning about evidence;
- modifying ideas in the light of evidence;
- developing 'bigger' ideas from 'smaller' ones.

The teacher feedback comments were analysed to determine if teachers appeared to be providing opportunities for these student roles to be met.

6.3 Learning actively (mentally and physically)

This role overlaps with some of the 5E phase purposes, for example, 'provide experiences of the phenomenon or concept' (*Explore* phase) and the SIS condition that 'students are encouraged to actively engage with ideas and evidence'.

Further support and examples that this learner role was present in these Primary Connections teachers' classes is in sections focusing on these areas (*see* sections 5.1, 5.2 and 10.4). This learner role is exemplified in:

> The children really liked the (CD) science unit, they found it challenging and worth the effort when they achieved results or got to the end of their investigations. They liked how we did science outside the classroom (when melting the ice blocks) and that it was a fun way to learn. (9G: CD)

In the following, some typical examples are provided to further exemplify that this learner role has been very well addressed in teachers' feedback comments.

In the EP unit, many teachers referred to students building orreries to represent their mental models and debating ideas, as in the 'Galileo lesson'. Within the separate phases of the CD unit it was obvious in all teachers' comments (9/9) in the *Engage* phase that active physical and mental learning was occurring as students explored the 'mess scene' as detectives. Furthermore, numerous teachers' comments about fair testing (e.g., in WM, CD and MM, as in sections 5.2 and 5.4) and problem-solving (with *electric circuits* in EC) clearly shows this role being met. In the latter, for example, 'students understood [the] circuit through the globe and got the concept well' (T6, L4) and: 'great lesson, students began to relax, try other ideas and were really engaged in the process' (Ts 13, l4). Active physical and mental learning was obviously present in the PP floating and sinking lesson, with all teachers (7/7) reporting on students' actions and thinking. This role was also evident with the youngest learners as an OTM teacher commented: 'Good mixture of discussion (sitting still) and moving (observing, walking, purposeful play, role-play)' (T4G: OTM).

'The children really liked the (CD) science unit, they found it challenging and worth the effort when they achieved results or got to the end of their investigations. They liked how we did science outside the classroom (when melting the ice blocks) and that it was a fun way to learn.'

There were some comments that were not consistent with this role, where, for example in the MMat sequence, three teachers thought there was 'too much teacher talk' (4G) or too 'teacher directed' (5G) and lacked 'investigating' opportunities (6G). Furthermore, 'learning mentally' seemed impeded for some students in a few classes (e.g., SA) because they had a limited vocabulary. These issues may be contrasted with teachers in the same units that did not encounter these difficulties. Apart from teachers' differing perceptions about the content and pedagogy in some units (e.g., *see* sections 11.23 and 11.24), these varied views could be due to a wide range of contextual influences (*see* sections 2.54 to 2.56).

There are many reasons why this role was addressed so successfully in most classes across all units. Taking the MM unit as an example, teachers referred to students completing 'daily observation, discussion and recording … [keeping] the topic alive' and, in one class, with a digital camera (Ts 2, 23); the lessons being 'very hands-on science' (16); there were 'fantastic' and 'horror' things to look at, including under a microscope (Ts 17, 23); students were encouraged to follow up 'allergies to spores' (18); '… all students formulated their own questions and set up own experiments'; and the structure of the unit helped 'students become more independent and able to work well on an investigation planner (23)[52].

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These excerpts also indicate that many of the SIS conditions to encourage effective learning (as in Chapter 10) were met.

6.4 Discussing ideas

There were examples of this learner role in all units, and some teachers (e.g., T20 SS) thought their whole unit encouraged this type of discussion, for example: 'The unit opened up some interesting discussions and questions'. In the following are summaries for some units where this role was most evident. An example is provided for each stage and across two content strands, but these overviews are typical of most units analysed.

- In the ASS S2 unit there was 'a lot of discussion' (T14G *Eng*), including for vocabulary development (T9: *Eng*), fair testing (e.g., Ts 4, 6 *Exp*) and conceptual understanding (tensile, T5: *Exp*; transparent/translucent T14: *Exp*). When environmental matters were raised, there was 'a lot of rich discussion (T22: *Exp*) as well as in 'contrasting and discussing issues of worth of plastic' (T6: *Exp*);

- In the CD S3 unit a most positive comment was: '… all children want to talk about science, the connections they have made and their correct use of the science language' (T9G). Further, in the two *Explore* lessons, at least five teachers referred to discussion of ideas (Ts 1, 5, 7, 8, 9), and there were similar comments about later phases, for example: 'L5 Group work worked well, especially hearing the reasons for placement given by individual children' (6G: *Explain*);
- In the PP S1 unit the Predict-Observe-Explain strategy was referred to by three teachers in Lesson 3 and students' ideas would have been invited. In some other lessons teachers said: 'Children could really feel the upwards push of water … that really engaged the students' interest. Great vocabulary. Great discussion' (T1: *Explore* L4); 'Session 2—fantastic demonstration. Some really good comments by students' (T2: *Elab*);
- Even with the younger learners, as in OTM ES1, teachers reported valuable 'group discussion' (T8: *Eng*), with similar comments for the *Explore*, *Explain* and *Elaborate* lessons, as in: 'Most class members could contribute easily to discussion and refer to charts around the room' (T1: *Exp*) and, later, this same teacher added: 'Interesting concepts came up such as children predicting one container would roll in a circle because the top was wider than the bottom; children then wanted to test other round items' (T1: OTM *Elab*).

There were times that teachers indicated their guidance was required to encourage this role, as in helping students develop mind-maps (T8: SS *Eng*), and in some units discussion was not mentioned by teachers in particular phases, but overall, the above is the general impression obtained from reading teachers' comments.

There were also difficulties on a few occasions due to specific factors. In each instance there were contrasting teachers' views and/or changing teachers' views from phase to phase. In WM, for example, a teacher said how students' limited vocabulary impeded discussion (T11: WM), but others in this unit (Ts 1,2,8) expressed how well sharing ideas went, for example: 'Terrific information from children discussing different materials in classroom' (2 WM *Explore*) and:

> We put out items that were not suitable as an evaluation task and this created a lot of discussion about suitable materials between classmates and the whole class. (T11: WM)

In MMAT (on solids, liquids and gases) this learner role was most evident in the *Explore*, *Explain* and *Elaborate* phases (*see* below) in some classes, but surprisingly less so in the *Engage* phase. This may have been due to excess content (Ts 1, 2G, 3/3G, 10); complexity of ideas/too much reading (4G/4); perceived teacher direction (T6G), lack of relevance (T7G) and students' inability to express their thinking (about solids, liquids and gases). As indicated, there are many reasons why discussion can be limited. As a teacher who implemented the CD unit commented:

> Simply due to group dynamics can mean the difference between a full on discussion about theories and observations or sitting in silence because 'we have said it all—there is nothing left!!!!' (CD: 9G)

In the MMat unit the above factors may have meant, for these teachers, that opportunities were not taken to listen to, and discuss, students' ideas. However, in the later MMat phases, some of the same teachers commented that 'Point

8 resulted in lots of good conversation and thinking' (T3: *Explore*); '(Students) found it difficult to explain why they belonged, great starting point for discussion' (T11: *Explore*); 'The students were quite involved with balloon activity, with good conversations about reasons' (T9: *Explain*) and 'Great discussion came from this activity' (T2: *Elab*).

6.5 Using ideas to understand new events/phenomena

This learner role is especially related to the *Elaborate* phase, and examples of opportunities for learners to use ideas to try to understand new events/phenomena are in section 5.4 and summarised in Table 5.6. As outlined in that section, it was not always apparent that learners (and possibly their teachers) appreciated that the *Elaborate* phase was, in part, for learners to apply the key idea from the *Explain* phase in new contexts. What was apparent in some Primary Connections units was that some learners were using their ideas about fair testing and applying them (i.e., their ideas about fair testing, not necessarily a conceptual understanding from the explain phase) in different contexts.

6.6 Reasoning evidence

There did appear to be several teachers aware of students reasoning about evidence, but also some that cast doubt as to whether this was a key focus for them (and, hence, for their students). Of interest is that across all 16 units only two teachers used the term 'evidence', although there is no doubt many teachers required students to provide reasons for their ideas. 'Evidence' was referred to in the SS unit (which focused on the Earth's rotation, the explanation for day and night and, in relation to these concepts, investigations about shadows). In the lesson on 'Studying shadows' the teacher commented: 'Investigation evidence was excellent' (T6: L5 *Elab*). The term was also used in the CD unit, but more than likely it was due to the nature of the *Engage* task, namely a 'mess scene investigation', where 'evidence' was inherent in the description of the task; one teacher said: 'Students got right into the scenario and really enjoyed looking at the reconstructions of the evidence' (T5).

In other instances reasoning about evidence had to be implied from teachers' comments. Unlike the first two 'constructivist' learner roles, there were not numerous examples to draw on relating to reasoning about evidence. A few examples are provided below, sometimes with commentary[53]:

- In SS S2, the following suggests that evidence may have been discussed: 'Wrapped a large map around student to demonstrate night and day' (T1: Lesson 2); 'Students drew shadow on a map of the world then viewed from sun, moon, satellite from web site' (T5: L2); and: 'children came up with heaps of ways to correctly demonstrate' (T6: L4);
- Although sharing ideas was evident in most WM ES1 phases, it was not obvious that 'evidence' was the focus of the discussion; the following probably involved evidential talk: 'We put out items that were not suitable as an evaluation task and this created a lot of discussion about suitable materials between classmates and

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This list is not exhaustive; for further details across more units see those purposes in the 5E analyses that included references to 'evidence'.

the whole class' (11: *Elab*) and: 'We decided to use clay and the students thought about the effect the weather may have had on this material' (T5: *Elab*);

- In ASS there were several comments that suggested evidence may have been a focus (although the term was not mentioned). Feedback in the ASS *Explain* phase did suggest that evidence was sought (Ts 4, 6, 10, 11, 22), as in: 'With all (the) background on plastics, students were able to write well reasoned expositions' (T4: *Explain*). Reference to evidence was implied in several of the comments about fair testing: 'Children remained in group to determine what was/would be fair test' (T9: *Eng*); '... a lot of materials went missing but it allowed for discussion of fair testing within controlled environments' (T4: *Explore*). Reasoning (probably involving evidence) was probably present when teachers referred to how the tests were modified in the ASS *Elaborate* phase, for example:

> ... on table, measured how far water spread on towel or held strips of towel in water for 30 seconds (photos) (T2: ASS);
>
> As each group had different results, drew up graph for comparison, students had excellent suggestions as to how investigation could be carried out for more consistent results across class (4 ASS);
>
> Used circle of paper towel fastened with rubber band to cup which was a convenient size and children did not have to wait lengthy periods for results or have huge numbers of drops to count (14 ASS);
>
> A different way to test absorbency by dropping squares of paper towel onto liquid, details of investigation included. (15 ASS)

6.7 Modifying ideas based on evidence[54]

The *Evaluate* phase (*see* 5E analyses, section 5.5) suggested that some students did change their ideas[55], but it is not known whether teachers asked for 'evidence' for the changes. As with the previous learner role, it was more difficult to identify teacher comments that could be interpreted with confidence that students were fulfilling this role (because reasons for changing ideas were not apparent).

In ASS, some teachers made references to students 'learning a lot', clarifying understandings about fair testing (*see* section 6.5), 'understanding why different materials are used for a particular purpose' (Ts 5, 14) and changing vocabulary (T4: *Explore*), and together, these suggest change or extension of students' ideas, where evidence was part of the discussions. The following also seems to imply evidence was considered and ideas (possibly) modified (*see* italicisation): '... *finding out answers* by testing possibilities themselves provided a real sense of ownership of their learning' (T22G: ASS) and: 'The children who dug up materials each week *gained a better understanding* of biodegradability than those who waited longer' (T8: ASS *Explore*).

As stated in section 6.5, evidence was part of the *Engage* task in the CD unit and may not have been a focus of discussion as in an attribute of the NoS (*see* section 10.9). There were, though, other instances in this CD unit where evidence may have come to the fore in the modification of ideas as in (*see* italics):

> Evaporating the 10ml of water was terrific, so many ideas were generated and discussion was amazing. Smelling the perfume, evaporating 10ml of water and

54
It does need to be borne in mind that just because students have encountered evidence that is contrary to their existing views, it does not mean they will modify their views (e.g., *see* Skamp. 2012a).

55
Examples of where students changed ideas are not reiterated here; discussion in section 6.6 is limited to where 'evidence' may have been implied.

> melting activities were all terrific. These three sessions were terrific but took a lot of time. The children generated a lot of ideas and their enthusiasm for doing something so basic was amazing. They got a lot out of the experiments and *started to draw conclusions and offer explanations*. (T8: *Explore* L2 CD)
>
> One group *came up with physical/chemical changes classification themselves*—I just offered the words for the headings. (T5: *Explain*)
>
> Students love burning candles, managed line graph well. *They understand clearly that burning uses oxygen and the jar size is related to the amount of oxygen*. (T5: CD *Explore*)

'The children generated a lot of ideas and their enthusiasm for doing something so basic was amazing. They got a lot out of the experiments and started to draw conclusions and offer explanations.'

The EC unit provided an interesting instance of where the use of a specific strategy possibly led to students modifying their ideas:

> We had our 'Scientist in Residence' with us for a month … worked with her doing investigations. This helped to develop critical thinking/baloney detection of an effective scientist. We also used a 'Baloney Detection Kit' derived from idea of Carl Sagan to assist students develop investigating and questioning skills. (19EC L1)

When students engaged in the Predict, Observe & Explain (e.g., T1 L3PP) or the Predict, Reason, Observe & Explain (PROE) (T3: EC L4) processes, then, if ideas were modified, it could be assumed that discussion of evidence played a role:

> Students completed their own PROE record for their science journals, then contributed to a shared group PROE record for sharing in the class science journal. Students redrew cut away diagram of torch and was interesting to see the *growth in their understanding*. (3EC L4)

Ideas may have also been modified in the light of evidence when a teacher commented: '… helicopters were very successful. All children experienced success and realised how it is important to test and retest'. (4 PP *Elab*)

When teachers referred to the challenge in some classes of operationally defining variables in order to obtain more trustworthy results, then this could be where evidence may have helped in modifying some ideas (here the impact of forces):

> Some used a blackboard ruler like a pool cue and pulled back a certain number of cm in an attempt to define small and large pushes. Most did it successfully on the width of the table simply by pushing. (8SM L2)

Sometimes ideas may be modified simply with more careful observation, as is implied in the SZ unit: 'The before and after sketches of the worms were very telling. Most children's sketches were different from the before sketch' (T2: *Explore*).

With some of the youngest learners, in OTM ES1, evidence was probably sought in their (possible) change of ideas 'LS7 (grouping activity): Excellent! Good for scientific knowledge and oral justification. Good thinking task' (T4: L4 OTM).

6.8 Developing ‘bigger’ ideas from ‘smaller’ ones

This more unusual learner role relates to ultimately having some understanding of the major ideas that underpin our appreciation of how the world works. There is not a consensus about these ideas, although most syllabi refer to some form of them. An example would be the nature of matter and how the particulate model of matter helps us to understand how matter behaves. Key ideas about ‘Energy and change’ are other examples. The Primary Connections units are, in part, organised around some of these major ideas, but at levels suitable for primary students. Teachers who have an appreciation of constructivist theories of learning realise that moving towards an understanding of these ideas is a life-long process and that they cannot be taught as propositions.

Harlen (2009, p. 35) has a simple way of describing the notion of a ‘bigger idea’. It is an idea that explains a range of related phenomena, and such ‘bigger ideas’ have to be ‘created from “small” ones, developed through understanding specific events familiar to children’. This learner role then relates to the 5E analyses that refer to explanations and understandings, such as the *Explain*, *Elaborate* and *Evaluate* phases. It also overlaps with the SIS condition that ‘students are challenged to develop meaningful understandings’ (for more details *see* sections 5.4 and 10.5).

Explicit reference in teachers’ comments that alluded to this learner role were rare. One teacher hinted at it: ‘Wonderful to be able to work in depth with just the movement of Earth and Moon and not spread thinly over all planets.’ (T15SS)

Indications that students were building on smaller ideas were possibly:

> Debating our place (in space) allowed students to draw on their prior knowledge of *Spinning in space*. They also had a good knowledge of terminology, orbit/rotate. (T11: EP parentheses added)
>
> They are starting to get concepts of Earth Days and Earth Years, especially since working with models, (T8: EP Lesson 5, while considering the solar system)

In some units Primary Connections provided the ‘bigger ideas’ that teachers could encourage their learners to engage with, such as ‘object’, ‘material’ and, perhaps, ‘property’ in WM ES1, but this was not apparent in teachers’ comments. A similar situation occurred in MMat where the word concepts ‘solid, liquid and gas’ are ‘bigger ideas’, but teacher comments rarely mentioned this learner role: a possible exception might be: ‘they made references to objects, even their lunches to solids, liquids and gases’ (11G MMat).

In a few units, depending upon an interpretation of ‘bigger ideas’, it may be possible to say that many students may have moved towards an idea that can generalise across contexts, as in the concept of an electric circuit in EC. Another case may be in CD, where some teachers reported that particular students had grasped some notion of physical and chemical change, for example:

> We added an extra bottle of straight water for this. We also dissolved a Panadol tablet as well as a Berocca tablet as the results could more easily be seen. The students seemed to understand the chemical reaction that occurred. (T10)

In an interesting example in the CD unit, several teachers referred to the apparent success of students learning about particles (Ts 2, 6, 7, 8, 9), one of the more abstract ideas underpinning out interpretation of how our world works. These teachers said:

> The perfume bottle investigation in Session 3 really demonstrated the concept of particles. (T6: *Explore* L2)
>
> The 2 notions of liquid (to) gas and the way the particles would look like was extremely strong. (T9: *Explore* L2)

This example does raise the question of whether what teachers believe to be successful is in fact the case. There is considerable evidence (summarised in Skamp, 2012b, c) that standard teaching about the particulate nature of matter with primary students is usually ineffective, but that more sophisticated pedagogical approaches can have success in moving students' models of particulate matter forward. The 5E model may be helping in this regard but further research would be needed to confirm if this was happening for this 'big' idea.

6.9 Teacher roles from the constructivist perspective

Harlen (2009) suggested that various teachers' roles can encourage the above learner roles. Selected examples[56] from the teachers' feedback comments are provided below to indicate whether some of these teachers appeared to fulfil these roles.

Apart from making provisions for the above learners' roles, the teacher roles are:

- Finding out learners' ideas and skills by questioning, observing etc.
- Deciding on appropriate action based on learners' existing ideas and skills.
- Arranging for group and whole class discussion.

6.91
Finding out learner ideas and skills by questioning and observing

Teachers reported many examples of this happening in their comments. Some examples across stages and units are:

Learners' ideas

> I found this (TWLH) very useful in determining what students' misconceptions were. (T19 SS; similar comments for mind maps T2; drawing T17)
>
> … made a chart and followed up with a magazine hunt (two charts—move by themselves, something else makes them move). Ss added a picture for each chart. (1 *Eng* OTM)
>
> Students experienced difficulty understanding the concept of a cutaway diagram, required much scaffolding—but produced *excellent* results. (3EC L1 emphasis in original)

56
The examples are not exhaustive but illustrative.

At times teachers did indicate that there were difficulties determining students' ideas, such as finding the TWLH chart difficult to use (Ts 4,18 SS), students' limited vocabulary (T3: Wm *Explore*) and understanding of a cutaway diagram (T3: EC L1), but often there were additional comments that scaffolding overcame the problems (*see* above).

Learners' skills

> As each group had different results, drew up graph for comparison, students had excellent suggestions as to how investigation could be carried out for more consistent results across class. (T4: ASS *Elab*)
>
> Recording individually was difficult. A lot of time spent on teaching how to write in data chart. Start to model data chart after Step 1. (T1: PP *Eng*)

6.92 Deciding on appropriate action based on learner ideas and skills

Apart from actions to assist vocabulary development, the following are some selective examples that suggest the teacher varied the activity to assist learning (it is difficult to discern whether the teachers' actions are 'based on the learners' existing ideas' and, hence, the extracts are more problematic than in most other analyses):

> Starlab dome was more effective to demonstrate science outcome (T4: *Explain* SS). Wrapped a large map around student to demonstrate night and day (T1: *Explain* SS). Used plasticene people to put onto globe (T1: *Explain* SS).
>
> Devised a sheet that children completed about item from feely bag, used word wall to complete written parts (T4: *Explore* WM).
>
> Added food dye to ice blocks for visual effect and motivation (T8: L4 MMat); Melted chocolate drops in sun, then refroze, then shattered. Sucked a chocolate drop to feel change (T11 L4 MMat).
>
> Used diagrams of molecules to explain states (T1: L4 CD).
>
> Large coloured textas used as energy packets, and ice cream containers, not hats, used with symbol of battery, and red tinsel on ice cream container to represent globe. Carried two textas at a time and dropped only 1 to show that some energy dissipated through transformation to another form—heat/light, some kept going around the circuit, therefore battery not flat/exhausted all at once (T1: EC).
>
> I felt it helpful to cover aspects of static electricity so the children could gain greater understanding of the exchange of 'electrons'. I did a bit of work via diagrams to help in their understanding about electrons. It is the electrons that move when an energy source is applied to a circuit. Much 'free play'/experimentation time was given over the weeks as the children were given their own bag of equipment to keep (T17: EC).

6.93 Arranging for group and whole class discussions

The Primary Connections units expect all teachers to use cooperative groups for a range of purposes including discussion; it may be assumed that this occurred, and several teachers commented on the success of this strategy, although it was not universal. Examples of where teachers used whole class approaches are mentioned below. It usually was not stated that it was for discussion purposes (e.g., to clarify ideas and/or have students share ideas would be Harlen's expectations), but rather to model procedures and related matters.

> Some children had very little idea about mind mapping—modelled with whole class. (T11W SS).
>
> We put out items that were not suitable as an evaluation task and this created a lot of discussion about suitable materials between classmates and the whole class. (T11: WM *Elab*)
>
> Kids had trouble reading the procedural text. Kept asking teacher what to do. Teacher did steps one at a time with the whole class to overcome the difficulty children had doing this (T4: PA *Explore*).

6.10 Constructivist learner roles across the units

In summary, there is evidence that all of these learner roles were present in the implementation of some units. On the basis of the extracts discussed in this chapter, there are indications that some roles were met with greater ease than others, while some were more difficult to discern. Of these learner roles, those requiring students to deal with 'evidence' were less apparent, and it is problematic how much emphasis teachers are placing on students providing 'evidence' for their thinking. It may be present in Primary Connections lessons, but it was not obvious in the teacher feedback comments. Also the application of ideas to new situations, while present in some classrooms, may need further clarification of the purpose of the *Elaborate* phase, so that more teachers are fully aware of the understandings they are helping students to use or apply in new contexts. Finally, 'developing 'bigger' ideas from 'smaller' ones' may have been incidental to teachers' thinking, although there were some examples of it. There would appear to be some merit in suggesting teachers' attention be drawn to these three learner roles.

On the basis of the 5E and the SIS analyses (the latter, in Chapter 10) judgements were made as to the presence of constructivist learner roles across all 16 units. An example of the resultant tables for the *Spinning in space* unit is in Appendix 6.1. Tables for each of the 16 units were prepared. Table 6.1 was prepared on the basis of the data in all 16 units; it indicates what these analyses suggest about the likely distribution of these roles (based on the content of teachers' comments) across all 16 units.

6.11 Implications for the implementation of Primary Connections: a constructivist perspective

A summary of the findings and insights from this constructivist perspective is in Chapter 12 (section 12.61). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

Chapter 6

Table 6.1: Extent to which the constructivist learner roles were explicit/implicit in teacher feedback comments across 16 units

Learner role	Extent
Learning actively (mentally and physically) is obvious in most units	Very high
Discussing own and others' ideas	Very high
Using ideas to try to understand new events/ phenomena	Moderate
Reasoning about evidence	Low
Modifying ideas in the light of evidence	Low
Developing 'bigger' ideas from 'smaller' ones	Moderate

Meaning of 'Extent' ratings: if about 5 or more imply the role in 75% or more of the units, then 'Very high'; 50% or more 'High'; 25% or more, 'Moderate'; less than 25% 'Low'.

Chapter 7

The inquiry focus in Primary Connections

7.1 Harlen's inquiry lens, Primary Connections and the 5E model

As stated in Chapter 6, Primary Connections has an inquiry-oriented and investigative approach embedded in its 5E model. In this chapter, teachers' feedback comments are analysed through Harlen's inquiry lens.

It is generally accepted that there is a direct interaction between students' use of enquiry skills and their development of conceptual understanding (e.g., *see* Harlen 2009; Traianou, 2006; Tytler & Peterson, 2003, 2005). Furthermore, this relationship is affected by the rigour with which inquiry skills are practised (e.g., how carefully a fair test is carried out or how meticulously an object is observed). 'Concepts of evidence' are at the heart of this connection; they refer to ideas and decisions related to 'the design of a test … measurement … data handling … and the evaluation of data', all of which help to answer the questions 'What has to be thought about when collecting data to help solve a problem or answer a question?' and 'What has to be considered to make sure the data (evidence) collected is believable (to oneself and others)?' (Feasey, 2012, pp. 62–63). In describing inquiry, Harlen (2009, pp. 38–39, parentheses added) makes the critical point that:

> Scientific inquiry, then, in more simple terms, involves not only the use of skills relating to the collection and interpretation of evidence but the development of models of how the natural world works. Without this there can be lots of action—observing and recording, even predicting—but not much of the other skills (e.g., hypothesising, designing fair tests, interpreting data, evaluating) that mean that their (students') minds are engaged and they are developing their own understanding.

On this basis, various learner roles from an inquiry perspective were posited by Harlen (p. 40) and are listed below. They are another useful lens to use in surveying teachers' feedback comments.

- Collecting evidence (first-hand and from secondary sources) about the world around.

- Using enquiry skills (observation, prediction etc.)
- Learning actively (mentally an physically)
- Reporting and discussing evidence
- Reasoning with others about how different ideas fit the evidence (argumentation)
- Reflecting on learning processes and outcomes.

Teachers' references to these learner roles are discussed in the following sections. Some are combined, as they tend to 'work together' in many instances. As in Chapter 6, references are made to other chapters when overlap occurs.

7.2 Collecting first-hand evidence about the world, and learning actively (physically and mentally)

These are two attributes integral to this inquiry perspective. Both were very strong features in teachers' comments. In all 16 units students were engaged physically and mentally, and in collecting first-hand data. Active learning is obvious from analyses determining if the 5E purposes were addressed (*see* Chapter 5), that the SiS component—'students are encouraged to actively engage with ideas and evidence'—was present (section 10.4) and if constructivist learner roles were present (Chapter 6). Collecting data was apparent in all *Engage*, *Explore* and *Elaborate* phases, and sometimes in *Explain* and *Evaluate* phases (Chapter 5). Data were mainly collected by observation, which at times included measuring. Table 7.1 indicates when teachers referred to observation and measurement, but these would be minimum estimates, as when students are involved in fair testing they would also be observing, and often this would involve measuring.

Some exemplary instances of active learning were bread-making (in MM), observation and care of invertebrates (ants, worms, snails) and pets (in SZ and SA), exploring various electric circuit arrangements (EC), testing helicopters (SM), schoolyard observations of objects and materials (WM), and shadow stick investigations (SS). In all these examples there were teachers who indicated that learning was minds-on as well as hands-on: reference was made to discussion, use of rich language, logical thought processes, applying learning in a meaningful way; before/after drawings; information reports; solving problems (as in getting a circuit to work); debate and argumentation about mental and physical models (of Earth, Sun and Moon movements); and numerous fair testing tasks (as in, e.g., testing of the properties of materials) (from MM; SZ; SA; EC; PP; CD; ASS; EP).

PC FINDINGS

Primary Connections has enabled many teachers to engage in assessing their students' progress in science.

Mental activity was also extended in some units, such as *Smooth moves* S2 (which a few teachers/students found more difficult). Interestingly, in *Push-pull* S1 the POE strategy was suggested: two teachers (Ts 1,4) found it easy for their students, another (T5), however said their students found forming explanations too difficult.

7.3 Using inquiry skills

An indication of the range of science inquiry skills (SIS)[57] mentioned by teachers is captured in Table 7.1. It suggests that observation and recording were mentioned on a regular basis and across all units. Measuring was less common and not referred to in five of the units. In all except three units predicting was mentioned, but usually less than the previous three inquiry skills. The frequency with which these skills were mentioned by teachers (and hence used in their classes) would, in most instances, be greater than shown in Table 7.1, as some teachers only described fair testing and did not mention the other skills. Fair testing would involve observing and most probably measuring, predicting and recording; in most instances in Table 7.1, when there are more teachers listed in the fair testing columns, there are less in the observation and recording columns, and vice versa.

It was rare for teachers to state that other inquiry skills were used; for example classifying was mentioned in MMat. Hypothesising, interpreting data and other related inquiry skills were not identified in the teachers' comments. This does not mean that these skills were not used[58], but it probably suggests that some of them were far less common, such as hypothesising (in the sense of giving reasons for making predictions and/or suggesting more general conclusions from observations for further testing). With reference to interpreting data, this would have occurred whenever teachers and/or students tried to move beyond their observations and measurements to make sense of what they were observing and measuring. Sometimes this would have been assisted by looking for patterns in the data, often by using tables and graphical means. Table 7.1 indicates that graphical forms of expression were mentioned in eight (of 16) units. However, several other modes, as shown in Table 7.1, were used by teachers to 'help students reconstruct and extend explanations and understanding' (in the *Elaborate* phase). On this basis, it is reasonable to assume that the wider range of inquiry skills required to advance conceptual understanding (as in Harlen's p. 40 extract) were being used in most, if not all, units. The extent and rigour with which students were using this wider range of inquiry skills is problematic, but some sense of their application can be discerned from some of the extracts in the following section (7.4) relating to evidence.

Selected extracts exemplifying these SIS follow. There are no extracts for observation and recording as they were numerous.

7.31
Observation and recording

These SIS were mentioned in all units. It was less common for teachers to expand upon how these skills were used, for example, for comparison purposes (e.g., T17: MM *Elab*). Sometimes there were difficulties in representing observations as with forces in the *Push-pull* and *Smooth moves* units. The extension of observation was mentioned at times by teachers; examples included using a magnifying glass (Ts 2, 4, 16 SZ *Explore*); microscope (T19: MM *Elab*); a flex microscope (T7: MM *Explore*); and a computer microscope (T1: SZ *Explore*).

Less common was reference to measurement. Two examples across the stages are measurement of mould growth with a maths grid (T4: MM *Elab*) and distance

57
They are referred to as 'skills' in this section, but it would be more appropriate to refer to them as processes.

58
Teachers may not have used these terms, but in searching the data alternative wording was noted.

rolled by objects on different surfaces (T5: OTM *Elab*). As indicated, measurements would have been part of most fair tests. Even with the youngest learners measurement sometimes was mentioned, for example, when they were measuring water consumption of animals (SA).

Recording was common to all units, although with some of the ES 1 classes, teachers had to assist or whole class records were kept. These records were sometimes prepared using computer word programs and could take pictorial and other forms (as described in various sections of this report, e.g., the use of an electronic journal). Records were assisted, at times, by digital photography (e.g., T23: MM *Elab*; T1: PP *Elab*; T6: CD *Explore*).

Table 7.1: Frequency with which teachers mentioned students using science inquiry skills (SIS)*

Unit	Predicting	Observing and recording	Measuring	Guided fair testing[a]	Less Guided fair testing
Weather in my world ES1	0	7, 9, 16, 17	9	0	-
Water works S1[b]	5 (3, 5, 11, 12,17)	4 (3, 12, 5, 14)	3 (2, 4, 16)	[1] (17)	-
Spinning in space S2	1 (2)	8 (2, 3, 5, 7, 9, 11, 14, 16)	3 (8, 14, 16)	1 (7)	-
Earth's place in space S3[c]	8, 9, 10 (When making models)	4 (1, 3, 5, 13)	0	3 (8, 9, 10) (i.e., working with models)	-
What's it made of? ES1	4 (1, 2, 5, 6)	7 (1, 2, 5, 6, 8, 10, 11)	0	[2] (3, 8)	-
Material matters S1	1 (11)	5 (3,11 + 1, 10, 14)	0	1 (7)	-
All sorts of stuff S2	4 (2, 6, 14, 22)	3 (6, 11, 13)	3 (2, 3, 4)	4[d] (2, 4, 10, 13)	-
Change detectives S3[e]	1 (9)	6 (2, 4, 5, 6, 9, 10)	3 (8, 9, 10)	5 (1, 5, 8, 9, 10)	-
On the move ES1	1 (1)	5 (2, 5, 6, 8, 9)	1 (5)	5 (1, 4, 5, [8, 10])	-
Push-pull S1	3 (1, 4, 5)	3 (1, 4, 5)	0	2 (1, 4)	-

*
The frequencies are minimum counts. Numbers in parentheses are those the teachers readily identified as mentioning the specific SIS. If a zero is included the skill was not directly mentioned in the comments, although it may have been subsumed within other SIS. Occasionally, other SIS were mentioned, such as classifying (sorting) (e.g., MMat Ts 1, 3,1 0, 11, 14 *Eng*).

a
Unless it was mentioned that students made various decisions, e.g., chose own variables, set up own investigation etc., it was assumed that the teacher guided the fair test. Numbers in round parentheses refer to implied 'field' investigations; those in square parentheses are 'investigations', but teachers did not, or very rarely, referred to fair testing (e.g., how much water an animal drank?; what happens when objects get wet; test which materials are electricity conductors; making all weather sculptures). If teachers said students did an 'experiment' without reference to SIS, it was not included in this table.

b
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. It is L6 (Investigating water use at home) and L7 (Water in other places) that is reported here.

c
Moon and star observations were in the EP unit, but teachers did not comment on these apart from some, who said they had difficulty getting students to complete this home task. Some classes did 'observe' computer simulations, but these are not recorded in the table. Most teachers reported that students made orreries (albeit several with equipment issues, but very few made

Smooth moves S2	0	2 (2, 8)	3 (3, 6, 7)	4 (4, 6, 8, 11)[f]	-
Electric circuits S3	3 (2, 3, 12)	2 (6, 11)	0	[4] (1, 6, 13, 19)	[3] (8, 12, 18)
Staying alive ES1	0	2 (2, 7)	4 (2, 6, 7, 8)	[6] (1, 2, 4, 6, 7, 8)	0
Schoolyard zoo S1	1 (2)	11 (1, 2, 3, 4, 5, 7, 8, 9, 14, 15, 16)	2 (3, 11)	(2)	-
Plants in action S2	0	3 (1, 9, 13)	2 (9, 20)	5 (2, 6, 10, 13, 20)	1 (4)
Marvellous micro-organisms S3	2 (19, 23)	5 (2, 17, 23, 24, 25)	1 (4)	4 (5, 6, 7, 18)	6 (4, 13, 17, 19, 22, 23)

mention of how they could have been used to 'test' students' ideas about celestial movements.

d
In ASS, there were four *Explore* lessons and an *Elaborate* lesson, and they all required (fair) testing; the number indicated here are the teachers who actually referred in some way to fair testing.

e
The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of CD S3. Lesson 6 in the draft version is the basis for the data reported here.

f
In SM S2, two teachers (2, 6) considered that 'measuring' the strength of the force and other 'measurements' were too difficult, while others felt their students could not draw a suitable graph (1,5,6,11); other teachers devised ways to assist their students to measure these quantities. Teachers' numbers were only included if the considered problem(s) was overcome.

7.32
Predicting

Predictions were a regular feature in most units. Sometimes teachers added that these predictions were tested. It was less common for teachers to say that reasons for predictions were sought. It may be assumed that students made predictions if fair testing was mentioned, although, again, it is not known whether students were asked for reasons for the predictions. The 'Investigation Planner' in Primary Connections (found in most units) includes a section for making predictions.

A few teachers clearly indicated that reasons for predictions were expected, as with the PROE strategy[59]:

> Students completed their own PROE record for their science journals, then contributed to a shared group PROE record for sharing in the class science journal. Students redrew cut away diagram of torch and was interesting to see the growth in their understanding (3) .... Such excitement when the first globe was lit! (T3: EC L4)

Providing reasons can be expected of students at all levels, as in:

> Interesting concepts came up such as children predicting one container would roll in a circle because the top was wider than the bottom; children then wanted to test other round items. (T1: OTM ES1 *Elaborate*)

The following indicates that predictions were tested: 'Ran parallel experiments to help them test their predictions' (T19: MM *Elab*); 'a very successful lesson, the visual results clarified concepts discussed, predicted by students'. (T23: Mm *Elab*)

59
The PROE strategy was only mentioned by two teachers across 16 units.

7.33
Fair testing

> In Primary Connections fair testing is an integral component of Investigating Scientifically (Hackling & Prain, 2008). Fair testing can be implemented with different degrees of guidance from the teacher (e.g., *see* Bybee, 2002) and, apart from below, specific examples are in other sections (e.g., section 5.41). It is more guided if teachers are making the decisions for most of the steps in the design and carrying out of the fair tests, and more open if students are making more of these decisions. On a few occasions, teachers made reference to the value of previous work on fair testing and how students were becoming more proficient in its use. (e.g., T13: ASS *Explore*)

Fair testing: guided

In these instances additional assistance appeared to be provided by the teachers. Some comments and/or an example from each stage are provided:

ES1

In OTM, one teacher commented:

> Interesting concepts came up, such as children predicting one container would roll in a circle because the top was wider than the bottom; children then wanted to test other round items. (T1: OTM *Elab*)

In session 2 of this phase the movement concept was extended through the use of a fair test that the students understood (Ts 1, 4). It was not mentioned what concept was being applied in the new situation (e.g., movement affected by the nature of the surface), although one teacher added: 'Children could give me the language (smooth/rough)'.

Stage 1

In SZ, fair testing was not mentioned but two teachers (Ts 2,4) referred to students comparing environments/animal housing with one suggesting predictions. In MMat 'Children designed an umbrella to test water resistant materials. Did this lesson after watching video in Lesson 1. Follow up with children testing 5 fabrics for suitability for raincoats' (T7: fair testing was assumed).

Stage 2

In PA, several teachers' comments suggested that the 'Investigation planner' was introduced in this unit. It was the first major investigation this group has done. The investigation planner made it easy to set up'. (T20: PA *Elab*)

MM S3

'An excellent lesson to ensure that students understand how to test scientifically. Instructions are clear and easy to follow' (T5: Mm *Elab*); 'Strong introduction to fair testing ...'. (T7: MM *Elab*)

Fair testing: less guided

This was where students made more of their own investigation decisions. It was less common but was still mentioned in some units. An example was in MM:

> Great interest created by moulds … all students formulated their own questions and set up own experiments …. Were genuinely interested in and predicted outcomes of experiment. (T19: MM *Elab*)
>
> Structure of unit has been successful in helping students become more independent and able to work well on an investigation planner. (T23: MM *Elab*)

7.4 Inquiry and argumentation: discussing evidence and reasoning how different ideas fit the evidence

These two attributes of an inquiry perspective need not be implied in the above characteristics. They suggest that teachers need to provide opportunities for student-student and teacher-student/teacher-class engagement with at least *the data collected*, *what the data means* and *how it supports interpretations that students* (and *teachers*) *offer*.

In all units, teachers mentioned that students were reporting and/or recording what they saw. SZ S1 is an obvious example where drawing of invertebrates was a key focus. Only one teacher added that before and after 'close looks' of a worm 'promoted a lot of thinking and discussion' (T4: SZ S1). In other units, there were contrasting reports from teachers indicating students were successfully drawing diagrams, completing graphical work or making physical models for testing mental models (e.g., of Earth, Sun and Moon 'movements') to, at times, other teachers mentioning difficulties (e.g., representing forces, appreciating how to 'test' students' mental models [of Earth, Sun and Moon movements] with the physical models).

'An excellent lesson to ensure that students understand how to test scientifically. Instructions are clear and easy to follow.'

In general, it was not readily apparent from teachers' comments that teachers were seeking evidence from students in order to relate observations to their interpretation, although, as discussed, there is qualitative and frequency data from the *Elaborate* analyses (section 5.4) that suggests that it would have occurred in some, possibly most, classes. However, as Harlen (2009) cautions, this reading of the teachers' comments may need to be more conservative.

As just implied, instances where both learner roles were probably occurring were less readily identified but were present in units. Some examples are provided below and wording is italicised in some extracts as they more clearly indicate that reasoning and evidence were present.

In EP

This unit was different, in that students constructed models (orreries) of their predictions about the movements of the Sun, Earth and Moon. In a few classes, reference to evidence would seem apparent:

> They really loved making the orreries and gave suggestions to one another. They worked in groups but each made their own model (T8: EP *Eng*) … [and later] they

started to get concepts of Earth Days and Earth Years, especially since working with models. (T8: EP *Elab*)

The students made awesome, moving models with their cut outs and *wrote explanations which really showed they have pulled everything together* so far. A brilliant activity. (T9: EP *Explore*)

In EC

Two teachers (Ts 3,6) used the PROE approach, which required students to support their ideas with reasons, and these were shared as a class (with T3[60]):

> Students completed their own PROE record for their science journals, then contributed to a shared group PROE record for sharing in the class science journal. Students redrew cut away diagram of torch and was interesting to see the growth in their understanding. (T3 EC L4)

60
The other teacher thought PROE, as presented in *fair testing*, restricted 'dialogue'; this, it seems, would depend on how the teacher implemented PROE, as it is a more powerful strategy than POE.

Another teacher (T1: EC *Elab*), following the Primary Connections suggestion to invite teams to share ideas (about testing for electricity conductors), said: 'Children … enjoyed sharing their ideas when asked for evidence'. This was one of the very rare occasions that a teacher used the term 'evidence'.

In CD

Three examples were: 'Students enjoyed the challenge of observation and *understanding what they were looking at'* (T4: CD S3 *Eng*); and

> The students counted the number of seconds before they could smell it and also the number of seconds it took to evaporate—the porous newspaper was first but the students initially thought that this would happen to the white paper first—because it was cleaner. They recorded the length of time for the perfume to evaporate depending on the amount—1 drop, 2 drops etc. used. (T10: CD *Explore*)
>
> Evaporating the 10ml of water was terrific, so many ideas were generated and discussion was amazing. Smelling the perfume, evaporating 10ml of water and melting activities were all terrific. These three sessions were terrific but took a lot of time. The children generated a lot of ideas and their enthusiasm for doing something so basic was amazing. (T8: CD *Explore* L2)

In MM

> This proved to be a fantastic way to learn about micro-organisms/mould/fungi. The students were rapt, loved all the experimenting involved too. Helped them test and see if their predictions and *logical thought processes were correct or not.* (19G MM *Elab*)
>
> … the visual results *clarified concepts discussed*, predicted by students. (23MM *Elab*)

In SZ (if the discussion related back to classroom observations)

> Wonderful lesson which worked really well to further students' knowledge of snails and ants and the *differences and similarities between the animals*. Session 2 *Antz* movie was wonderful for comparison. (T4: Sz *Explain*)

PP

> Children's labelled (force) diagrams were fantastic, *as were their explanations*—what a great assessment tool.(T1: PP *Elab*)

7.5 Assessment of SIS: reflecting on learning processes and inquiry outcomes

Assessment of SIS was apparent in teacher comments discussed in, for example, section 9.72. Some examples are:

> Children designed their own fair test using procedure from L2 as guide. Came up with similar to RS2. Was great assessment of knowledge of fair testing and procedure genre. (4MM *Elab*)
>
> An assessment task was to draw an ant on the computer on *Kidspix* and label. The children thoroughly enjoyed this and have gone on to do it with snails. (7: SZ *Explore*)
>
> Students said it had been fun learning about different properties. (14: ASS *Eval*)

Revision of fair testing was also mentioned in various units, suggesting that students may have encountered it in earlier Primary Connections units, for example: 'Visited fair testing again' (T7: MM *Elab*) and 'good revision of fair testing'. (T18: MM *Elab*)

7.6 Overall strength on inquiry perspective across analysed units

On the basis of the 5E analyses, aspects of whether the SiS conditions were addressed (Chapter 10) and the above focus on an inquiry perspective Table 7.2 was constructed. It rates the strength of this perspective on the basis of whether students are making inquiry decisions, the variety of science inquiry skills mentioned and the frequency and content of teacher comments about inquiry in the implementation of the Primary Connections units. Apart from WW, all units have either a moderate (3), moderate to strong (5), strong (6) or very strong (1) inquiry perspective orientation[61]. This is a most positive outcome for Primary Connections units, considering the wide variety of content areas, the diversity of teachers and students, and the contexts within which they were implementing Primary Connections units. Furthermore, the impression obtained from carefully reading the teacher feedback comments is that science in these classrooms is infused with (mostly successful) attempts to make (scientific) inquiry part of primary science. As indicated in other chapters, in this report (and in the following section) there are still many challenges to be overcome, but these Primary Connections teachers have shown what is possible.

61
This is probably a conservative estimation, but it is taking many inquiry characteristics into consideration.

7.7 Implementing an inquiry perspective: other issues

Various issues emerged as a consequence of this focus on inquiry processes and skills. These are:

- Limited 'testing', fair testing and/or field testing (as in MMat) does not mean that the unit was not successful for some classes, for example:

'Children loved the mystery objects game. Children REALLY loved hands-on investigation, allowed children to explore properties'. (T11: MMat L3, emphasis in original)

- Sometimes student focus and excitement was on the phenomenon (e.g., wanting plants to live; becoming competitive in testing catapults; excitement with physical and chemical changes), and this detracted from ongoing and ensuing productive discussions. This happened in some units across all stages (T6: PA *Elab*; T6: SM *Elab*; T2: CD *Eng*). It suggests that teachers need to be patient and persistent in helping students become proficient in fair testing; considerable pragmatic advice is available (e.g., *see* Harlen, 2003; Feasey, 2012), including moving from a guided to a less guided approach (as described in Hackling, 2005). Pervasive management strategies may assist (Harris & Rooks, 2010).
- Fair testing needs to be introduced in a structured manner; if a step (e.g., identification of the question) is overlooked then other steps may be meaningless as reported by one teacher. (T13: PA S2)
- In a unit with minimal fair testing (MMat) at least two teachers requested more testing opportunities be inserted. This suggests that some Primary Connections teachers now expect fair testing to be integral to their science classes
- In some classes students found aspects of fair testing difficult:
    - writing investigation questions (T6: PA S2);
    - graphing (e.g., T6: PA S2);
    - predicting (e.g., T3G MMat S1);
    - drawing (Ts 1, 23 SZ S1); and
    - testing (e.g., T3G MMat S1).

There is practical advice about each of these areas that can help teachers. The Primary Connections units do address some of these skills. Additional help may be found for particular skills, namely for graphing (Feasey, 2012); drawing (Tytler, Haslam & Peterson, 2012); and testing (Harlen & Jelly 1998; Hackling, 2005).

- Fair testing or simply 'testing' or 'problem-solving' (i.e., the latter two without reference to controlling variables) in some ES1 classes was considered too complex by some teachers (e.g., 'designing' a wind meter [T4: WW]), yet other ES1 teachers reported success with guided fair testing. There are many examples of successful fair testing with young learners in the literature (e.g., Goldsworthy & Feasey, 1997)
- In the unit SM S2, three teachers (4,6,11) reported that fair testing progressed well in their classes (although there were student difficulties with recording and/or graphing), while three others raised issues they believed hindered the fair testing. Overall, whether the classes completed the fair testing or not, the issues raised were equipment (Ts 10, 3, 6) students' inability to keep variables the same (T7); teachers believed concept too difficult for students (Ts 3, 5); students had difficulty recording (T4) and graphing (Ts 6,11); teacher had difficulty with variables grid (T7), and students did not understand variables (T5) and fair testing (Ts 5, 10). One of these said the 'achievement of investigating outcomes was almost nonexistent' (3SM). Although there are several teachers' comments that indicate that students can sometimes appear to appreciate fair testing on its first use and students can improve in their approaches to fair testing with experience, it cannot be assumed that this will be similar for all teachers and their classes, and across all content areas.

Table 7.2: Strength of inquiry perspective in units based upon content and frequency of teacher comments*

Unit	Strength of inquiry perspective	Comments
Weather in my world ES1	W–M	Teacher comments focused on vicarious tasks
Water works S1[a]	M–S	Frequent predicting and observing, occasional testing but fair testing (FT) not apparent. Water cycle, sources of water etc. tended to predominate
Spinning in space S2	M–S	Many observations, measurements and recording; few mentions of predicting and testing
Earth's place in space S3	M	Contrast between a few classes that used models for making and testing predictions and several that did not report that models were used in this manner
What's it made of? ES1	M–S	Most emphasis on predicting and observing; limited reference to testing (sculptures)
Material matters S1	M	Key focus appeared to be recognising and sorting solids, liquids and gases; very limited mention of testing; FT not mentioned
All sorts of stuff S2	S	Numerous indications of 'testing' materials, even though mention of FT not as obvious; predicting present
Change detectives S3[b]	S	Many investigations cited (even if FT not mentioned); scenario encouraged many observations and inferences
On the move ES1	S	Impressive investigations (including measurements) for S1 students
Push-pull S1	M–S	FT rarely mentioned and limited mentions of SIS; relatively small teacher response rate
Smooth moves S2	M	FT very successful for some; too many difficulties for others
Electric circuits S3	S	Focus was more of a 'problem-solving' approach than FT (although one teacher raised FT)
Staying alive ES1	S	Key focus on senses; also pets and their features. Some references to a descriptive investigation
Schoolyard zoo S1	S	Major focus on observing/drawing animals and their movement; rare reference to investigations per se
Plants in action S2[c]	M–S	Tendency to focus on plant growth per se; fewer distinct FT descriptions
Marvellous micro-organisms S3	VS	Less guided FT obvious; numerous SIS skills employed

*
VS = very strong (less guided fair testing (FT); wide variety of SIS; many teacher (T) comments); S = strong (FT; variety of SIS; considerable T comments); M = moderate (limited FT; some SIS; few T comments); W = weak (No FT; limited SIS; minimal T comments). A judgement is made with ES1 units in which FT was rarely suggested; 'investigating was interpreted more broadly'.

a
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. It is L6 (Investigating water use at home) and L7 (Water in other places) that is reported here.

b
The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of CD S3. Lesson 6 in the draft version is the basis for the data reported here.

c
It appeared that the 'Investigation planner' may have been used for the first time in many of these classes.

7.8 Inquiry learner roles across the units

In summary, there is evidence that all of these learner roles were present in the implementation of most units. On the basis of the extracts discussed in this chapter, there is an ethos of inquiry in many Primary Connections classrooms, although those learner roles requiring students to deal with 'evidence' were less apparent (as in Chapter 6). There were fewer mentions of some SIS and less guided investigation was far less common than guided investigation. Teachers may benefit from guidance about levels of scaffolding that could lead to more open investigations.

On the basis of the 5E and the SIS analyses, judgements were made as to the presence of inquiry learner roles across all 16 units, as in Chapter 6. Table 7.3 indicates what these analyses suggest about the likely distribution of these roles across all 16 units, based on teachers' feedback comments.

Table 7.3: Extent to which the inquiry learner roles were explicit/ implicit in teachers' feedback comments across 16 units

Learner role	Extent
Collecting evidence (first hand and from secondary sources) about the world around	Very high
Using enquiry skills (observation, prediction etc.)	Very high
Learning actively (mentally and physically)	Very high
Reporting and discussing evidence	High
Reasoning with others about how different ideas fit the evidences (argumentation)	Low
Reflecting on learning processes and outcomes	High

Meaning of 'Extent' ratings: if about 5 or more imply the role in 75% or more of the units, then 'Very high'; 50% or more 'High'; 25% or more 'Moderate'; less than 25% 'Low'.

7.9 Implications for the implementation of Primary Connections: an inquiry perspective

A summary of the findings and insights from this inquiry perspective is in Chapter 12 (section 12.62). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

Chapter 8

Language focus in Primary Connections

8.1 Harlen's 'talk lens', Primary Connections and the 5E model

As stated in Chapter 6, Primary Connections' adaptation of the 5E model has the expectation that students will 'represent and re-represent their developing understandings using a wide range of texts…'. In this chapter teachers' feedback comments are analysed through Harlen's language/talk lens. Cross-references are made to other chapters where there is overlap.

8.2 Analysing teacher comments through a language lens

In this research project, the teachers' comments were specifically searched for indicators of 'discussion, dialogue and argumentation'. These three aspects of 'talk' derive from Harlen's (2009) review of learning in science, which contends that, along with constructivism (individual and social), enquiry and formative assessment, 'talk', as expressed through these three categories, can contribute to a robust approach to learning and teaching.

Harlen (2009) argues that 'it is through language that we develop a shared understanding of ideas'; hence, discussion must have a place in primary science. This talk is often to be 'informal' and 'exploratory' between students and student(s) and teacher; 'dialogic teaching' needs to come to the fore and 'argumentation' have a strong role. Dialogic teaching is different to a 'question-answer-tell' approach; it is where 'talk' is a stimulus to challenge and extend student thinking (as well as having formative assessment roles for both teacher and students). Teachers (and, over time, students) can engage in this type of dialogue in science by focusing their thinking and talk on the use of evidence. 'Argumentation', as used here, has a special meaning: in science it is 'ideally about sharing, processing and learning about ideas' and efforts to persuade others of the merit of an idea based on the available evidence. When teachers have used, for example, concept cartoons in the *Engage* phase in Primary Connections and not closed the discussion, then they may have been engaging in argumentation. This would be especially the case if students were asked for their reasons (evidence) which could then become the subject of further dialogue in the *Explore* phase (Harlen, pp. 36–37, adapted, with extensions and additions).

The three learner roles teachers need to encourage associated with discussion, dialogue and argumentation are:

- explaining their own ideas to others with examples where appropriate;
- listening and responding to others' ideas;
- using language appropriate for explaining scientific phenomena (Harlen, 2009, p. 40).

In the following, a search of teachers' comments has been made to determine if there are indications that students have been given opportunities to experience these roles.

8.3 Explaining, listening and responding

These two roles are combined partly because they overlap and also as they are similar to some of the 5E purposes that were the focus of the analysis in Chapter 5. Many teachers' comments suggest that discussion and dialogue, as outlined above, were present in various units. Aspects of argumentation[62] were also evident when students referred to the use of evidence.

Although somewhat superficial, comments in this section have been divided into a range of 'talk' categories to illustrate that teachers' comments were, at times, indicators of Harlen's three categories (italicisation has been used to emphasise the presence of the categories and roles). Aspects of these learner roles have also been discussed in the analyses of the 5E phases (Chapter 5), as some of the 5E 'purposes' of these phases were very similar to Harlen's 'language/talk' roles.

8.31 Discussion

There were numerous times that teachers referred to activities leading to 'discussion'; some instances may be found with teachers in SZ [Ts 1,3]; WM [Ts 1,2,4,8,11]; EP [T3]; SS [Ts 2, 9, 20]), as well as in many other units (typical extracts are in Chapter 5).

The descriptors teachers used at times gave the flavour of the talk in the discussions. Typical examples from a range of units included 'promoting a lot of thinking and discussion' (in T4: SZ L2, about before and after worm observations); '... but this (different group results) made for an excellent class discussion (T1: CD *Explore* L3); 'We discussed at length that *everything* they see was worth making a comment about on paper (T9: CD *Explore* L3 emphasis in original); '... students interacted well in discussion' (T21: ASS *Explore*); 'a lot of discussion and vocab. development in each session' (T14G CD); and '... lots of good conversation and thinking (3: CD *Explore*).

62
Argumentation has been analysed into various components over recent years in which teachers help students to distinguish different components and how they relate (e.g., Osborne, Erduran & Simon, 2004). Such a detailed analysis is not required here.

At times this 'type' of discussion did not eventuate as, for example, when students did 'not listen carefully' (T4: CD) or some had difficulty, or were very unfamiliar with the language in units (e.g., CD Ts 4, 9 *Exp*; WM Ts 1,9 *Eng*; and at least seven other teachers in the *Explore* phase); and, at times, terms may have been introduced too early (*see* T4: CD *Eng*). Advice about how to engage students in this type of talk is available (e.g., Newton, 2002).

8.32
Dialogue and explaining ideas

The way some teachers described what happened in their classrooms was suggestive of dialogue between students and/or between teacher and student(s); some examples[63] are:

- The (MM) 'activities drew all students into a meaningful dialogue' (T23G MM) and the students were 'talkative about (the) experiments.
- In EC *Elaborate* the students 'enjoyed sharing their ideas when asked for evidence'. (T1EC L6)
- There was a long exploration time, focusing on the properties of magnets, and students 'were beginning to see past the activities to the properties of magnets and to suggest other things to try', and they did not complete the Primary Connections tasks 'because they discussed then wrote about what they knew about magnets before moving onto…'. (T3SM L3)

63
Dialogue could also be 'read' into some of the above 'discussion' examples.

8.33
Argumentation

Although it may not have occurred when teachers used the POE (PP T1), and even more so, the PROE strategies (for details *see* sections 5.33 and 6.7), students may have been asked to support their claims with evidence. Further examples of students most probably talking to others about 'evidence' is in, for example, sections 6.6 and 7.4.

8.34
Other aspects of these roles

Explaining ideas and listening and responding to others was facilitated by many actions teachers took. Apart from examples in earlier sections teachers also commented that 'Think, Pair, Share' approaches 'worked very well' (T6: PA *Elab*) and that their students 'enjoyed shar[ing] their understandings [of forces] with their parents' (1PP *Elab* L7, parentheses added; also in EP T8 L3).

Although students 'sharing examples' has to be assumed from most teachers' comments, such as 'students 'worked well with a partner' (T2; also Ts 4, 8), occasionally it was explicitly mentioned, as in: 'Students discuss how toys move in pairs and share one example/pair with class' (T9 lesson T4 OTM); 'Most class members could contribute easily to discussion and refer to charts around the room (T1: OTM *Explain* L5); 'Group work worked well, especially hearing the reasons for placement given by individual children' (TG CD); 'They really loved making the orreries and gave suggestions to one another' (T8: Lesson 1 EP); and 'They were eager to express what they knew and wanted to share their ideas' (T1: L1 EP).

8.4 Using appropriate language for explaining scientific phenomena

An indication of *student* use of language that specifically referred to scientific content and terminology and was mentioned by teachers is captured in Appendix 8.1. This appendix also indicates how many teachers made comments about students using a science journal and the word wall, and if the comments were positive (P) or not (LP = Less Positive), as well as if the teacher omitted the use of these two aids. This appendix indicates that at least 34 teachers across all units made reference to students developing a science vocabulary. It also indicates that at least 43 teachers' classes were using a science journal and at least 40 teachers were using a word wall (and at least four did not).

The table represents *all* the comments made by teachers about students using scientific language across all 16 units. Extracts are therefore not repeated here. These teachers' comments indicate that:

- science vocabulary was a real consideration for many teachers (evident across all units) and students tended to enjoy expanding their vocabulary (e.g., ASS, CD);
- teachers assisted vocabulary development by introducing student-prepared dictionaries (Ww), glossaries (EP) and using the word wall and science journal (*see* below); 'big books', posters, charts and pictures also helped (WM);
- teachers appreciated the overlap with literacy goals (SS, OTM);
- occasionally, a lack of familiarity with new language was challenging or caused difficulties (WM, MMat, PP).

8.41
Science journal and word wall

Both these 'How to' techniques were appreciated by teachers, as attested by the frequency counts for their number of mentions. Some of their uses are provided below.

Word wall

Teachers' comments included: the Word wall was 'good to add descriptive words' (MM T3G); '(I) used it in Unit 1 and would use it again' (T5G [WWall] MM); and 'We put definitions of physical and chemical change on the information wall' (assumed to be the Word wall) (T1: CD *Explain*).

Interestingly, the word wall was effective for several CD teachers (Ts 2, 3, 10), but one teacher (T4) felt the need for Primary Connections to suggest the words that should be entered. The word wall is usually meant for 'words that students see, hear and use in their reading, writing, speaking, listening and viewing' (AAS, 2008b, p.68).

Science journal

Some teachers referred to the use of the science journal in every lesson (e.g., T10 CD) and others also saw it as an assessment tool (T1: CD). Some instances it was mentioned were: 'This time kids collected their own words in science journal, writing them on imaginative single celled critters' (T5G [WWall] MM) and 'Journals included some interesting diagrams but my young year 1 students included very few written labels' (2 PP *Explore* L2). Electronic journals were very popular with students when they were used (*see* sections 7.31 and 10.102).

8.42
General literacy

In this report general literacy was not a focus, but on several occasions teachers indicated particular units had a strong (general) literacy focus (e.g, EP), with teachers sometimes referring to general literacy outcomes, such as: 'Great unit for sorting words into grammatical functions of words and phrases' (T14G ASS) and 'We used marshmallows for class mystery object because of allergies. Children employed good descriptive language after first group or two had had their turn' (T6: SA L2).

8.5 Teacher roles to encourage 'talk'

Teachers' roles associated with these learner roles are:

- modelling skills of using talk productively;
- acknowledging students' ideas in a way that values them;
- asking for examples to clarify students' ideas; and
- expecting students to support their claims or ideas with evidence (Harlen, 2009, p. 40).

A detailed analysis was not completed to ascertain whether teachers fulfilled these roles. Teachers did model new skills and tasks, such as role-play (T8 SS), but whether they modelled 'science-talk' is not known. Certainly, several teachers would have acknowledged students' ideas in the *Engage* phase (e.g., with mind maps T2 SS) and elsewhere. There were comments that suggested that students' ideas were valued (*see* below) and that 'evidence' probably was considered even if not always explicitly discussed (e.g., *see* sections 5.32, 6.5 and 6.6). Some examples of each of these teacher roles are identified below.

8.51
Modelling skills of using 'talk' productively

In the PA unit, one teacher said: 'I gave students *a modelled example* of a Science Journal and we *deconstructed it* in small literary groups during a literary rotation'(T8 PA Science Journal), while another added: 'Science Journals involved a large amount of time ... *I put more emphasis on the talking/ listening than the writing*' (Tuk PA Science Journal).

These examples do not refer to how students could use talk to, for example, provide examples of what they mean or how to defend their ideas with evidence.

'The best aspect of this unit was that it provided hands-on activities for the students to engage with in a meaningful way.'

8.52
Acknowledging student ideas positively

The following indicates the teacher valued students' ideas:

> The abstract nature of the concept. However, because you are just 'testing' the ideas that kids have, there is a certain amount of freedom in the discussion. (T4: SM L1)
>
> The children thought of far more ways to move an ice-cream container than I did. (T10: SM L1)
>
> Teacher surprised about responses to questions at LS 2. (T2: *Eng* OTM)
>
> There was still some confusion as to what to categorise each card. Once we regrouped after the team exercise we were able to discuss the reason for each change placement. This helped classify. (T6: CD L5 *Explain*)
>
> This worked fairly well but we did argue a great deal about the differences between the changes and the fact that some can have both. (10 CD L5 *Explain*)
>
> The best aspect of this unit was that it provided hands-on activities for the students to engage with in a meaningful way, finding out answers by testing possibilities themselves provided a real sense of ownership of their learning. (T22G ASS)

8.53
Expecting students to support their claims or ideas with evidence

'Evidence', as a term, was not specifically mentioned in teacher comments (except for the CD 'detective' lesson and on one other occasion), but was implied in quite a few comments, for example (also *see*, e.g., 5.31, 6.7 and 7.4):

> Interesting concepts came up, such as children predicting one container would roll in a circle because the top was wider than the bottom; children then wanted to test other round items. (T1: *Elab* OTM)

8.54
Asking for examples to clarify student ideas

This would be a common teacher action, for example: 'Changed this to a cut and paste match up, as drawing lines often becomes messy and confusing for student and teacher'. (T1: OTM L5 *Explain*)

8.6 Language/talk learner roles across the units

In summary, there is evidence that all of these leaner roles were present in the implementation of all units. 'Using language appropriate for explaining scientific phenomena' could be more readily discerned, as teachers often mentioned students' development of vocabulary and ability to describe what they were observing and testing. It was a strong focus for most units. Students explaining their ideas to others could be ascertained at times, but the extent to which students were 'Listening and responding to others' ideas' was more difficult to discern from teachers' comments.

On the basis of the 5E and the SIS analyses, judgements were made as to the presence of 'language/talk' learner roles across all 16 units, as in Chapter 6.

Table 8.1 indicates what these analyses suggest about the likely distribution of these language/talk roles based on teachers' feedback comments.

Table 8.1: Extent to which the 'language/talk' learner roles were explicit/implicit in teachers' feedback comments across 16 units

Learner role	Extent
Explaining their own ideas to others with examples where appropriate	High
Using language appropriate for explaining scientific phenomena	High
Listening and responding to others' ideas	Moderate

Meaning of 'Extent' ratings: if about 5 or more imply the role in 75% or more of the units, then 'Very high'; 50% or more 'High'; 25% or more 'Moderate'; less than 25% 'Low'.

8.7 Implications for the implementation of Primary Connections: a language perspective

A summary of the findings and insights from this language perspective is in Chapter 12 (section 12.63). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

PC FINDINGS

All units provided experience of the phenomenon or concept, with many activities having a most positive impact on teachers and students.

Chapter 9

Assessment in Primary Connections: do teacher comments suggest it is embedded within the 5E model?

9.1 Assessment in Primary Connections

As stated in section 6.1, 'assessment (in Primary Connections) is integral with teaching and learning. Students' representations of their developing understandings provide opportunities for teachers to monitor students' learning progress and use this information to facilitate further learning' (Hackling & Prain, 2005, p. 8). This position is consistent with one of the SiS' conditions that facilitates effective learning in science, namely 'Assessment is embedded in the science learning strategy' (*see* Chapter 10).

Harlen (2009) also refers to assessment as a component of her emerging model of robust science pedagogy (*see* section 6). Her focus is on various aspects of formative assessment, which is strongly implied in the above quotation. Formative assessment is central to helping students to take ownership of their learning. To take ownership of one's learning, students need to be aware of the goals of their work and to have a sense of what it means to achieve those goals well. Formative assessment, therefore, implies four roles for students, namely, students need to participate in self and peer assessment (the former, especially, to identify next steps), agree on the standards of quality to apply in assessing their work and take responsibility for working towards the goals of particular activities.

In this chapter, teachers' feedback comments were analysed through an assessment lens, in a general manner at first and then using Harlen's learner roles in formative assessment. As in the previous two chapters, reference is made to earlier analyses where there is overlap with categories discussed in this chapter.

9.2 Analyses of teacher comments through an assessment lens

In broad terms, teachers referred to assessment in each of the 5E phases, although more frequently in the *Evaluate* phase. In the 5E phases, diagnostic assessment is mainly focused in the earlier phases (mainly in the *Engage* phase), formative in *Explore* and *Explain* phases, and summative in the *Elaborate* and *Evaluate* phases (AAS 2008a). Revealing students' ideas and beliefs, a purpose of the *Engage* phase, is a component of diagnostic assessment and has been discussed in section 5.1. The 5E analyses indicated some teachers endeavoured to recognise students' entering conceptions. The two purposes of the *Evaluate* phase (*see* section 5.5) had a summative assessment role, and focused on students' SU, whereas the *Elaborate* phase focuses on summative assessment of science inquiry processes and skills. In the following comments, aspects of assessment not identified in the earlier *Engage* and *Evaluate* phases' commentaries are the focus. Unless indicated, the comments included were the *only* ones teachers referred to in a unit.

9.3 Teacher assessment processes: impact of Primary Connections

Assessment of students' learning and progress in science at the primary level has not been a high priority compared to assessment in the areas of literacy and numeracy (cf. the National Assessment Program—Literacy and Numeracy [NAPLAN] testing process: ACARA, 2010). Primary Connections would hope that teachers implementing its units would be empowered to rectify this imbalance. Analyses from the *Engage* and *Evaluate* phases would suggest that Primary Connections is helping some teachers to move towards that goal, so that, as one said:

> Teaching these lessons has enabled me to feel confident about writing students' reports and commenting upon their scientific understanding about space. (T4G EP)

9.4 Teacher assessment of student learning

In several units, teachers' comments rarely made direct reference to assessment, but in others it was more common. Teachers' comments referred to diagnostic and summative assessment in the *Engage* and *Evaluate* phases (although they very rarely used this terminology). Beyond these phases there were at least seven of the 16 units analysed in which teachers made three or more readily discernable assessment comments (EP S3; MMat S1; ASS S2; CD S3; OTM ES1; SM S2). Some of the more general assessment aspects teachers mentioned are outlined next.

9.41 Impact of previous Primary Connections units on student learning

On a few occasions teachers referred to the influence on students' science learning of completing more than one Primary Connections unit:

> … children made links with (the) *Push/Pull* unit GREAT UNDERSTANDING! … a lot of quality learning took place. (T11G MMat S1)
>
> Of the few students that I had last year (when I also used Primary Connections) and again this year (I have a composite class), their bookwork was definitely the best and understood most about recording observations—building on top of skills is obviously the best practise. (9G CD parentheses added)

One teacher referred to conceptual learning across Primary Connections units:

> Ideal for revision of solid, liquid and gases (in the Mmat S1 unit) by developing an understanding that each substance needs to be held in an appropriate container. (T21: ASS *Eng* parentheses added)

Elsewhere in this report reference has been made to the positive impact on students' learning about forces in the SM unit if they had previously completed the PP unit (*see* section 4.26).

9.42 Appreciation of the relationship between assessment and learning outcomes

Although not regularly mentioned, several teachers did refer to 'linking assessment to learning outcomes' (T2G SS S2). Sometimes they referred to how successful the unit (or aspects of it) had been, as in: 'Excellent learning outcomes with children understanding why different materials are used for a particular purpose' (T14G ASS)—a summative comment, and 'students responded well to these questions. Good sequence of activities. Students were able to achieve lesson outcomes. (7 SA L3 *Explore*)—a formative assessment remark. On other occasions, the assessment-learning outcomes connection indicated further learning was required for some or most of the class:

> The answers from Resource Sheet 6 reflect how effective this unit has been in helping students achieve these outcomes. There is still a lot of confusion for the children'. (T9G: MMat)
>
> I had, I believe, approx. 4 students on level 4, approx. 12 students at level 3 and the remainder either level 2 or 1 (I do have a couple of very weak students). (T10 CD Assessment)

A suggestion made by one teacher also directly implied the assessment-learning outcomes connection when they added: 'Suggest Progress map for assessment eg Is beginning to … /Is able to … /Is extending in ability to …'. (T10G: LO MMat)

9.43
Limited time for assessment tasks

The lengthy time required to complete Primary Connections units was identified in several teachers' comments on completing a unit. This would have been related to some teachers not completing the *Evaluate* phase or parts of it (e.g., *see* T6 SS: part of *Evaluate* omitted due to time; EP 6Ts did not implement the *Evaluate* phase). Others made comments about the time element:

> … found most sessions fairly heavy with content to get through everything, yet still have meaningful content to make a fair assessment. (T13G EP)
>
> (Needed) time to answer questions and critically check any misconceptions. (T7: EP S3 L4)

9.5 Teacher comments on specific 'assessment' strengths and weaknesses

Teachers had the opportunity to directly comment on the strengths and weaknesses of 'assessment' in the units they implemented (it was a separate item on the feedback pro forma). In the 16 units analysed there were no comments made on this item in nine units, and generally very few comments in each of the remaining units[64]. This may mean that many teachers are either satisfied with the suggested Primary Connections assessment processes or that assessment was not uppermost in their thinking as they responded to the feedback pro forma.

On occasions, teachers made suggestions (in other sections of the feedback pro forma), indicating their awareness of assessment issues. In the ASS unit[65], for example, the following were identified: 'Need more concrete forms of assessment for those doing A to E reporting. New reporting puts assessment in a different light' (T12G EC ASS); 'Trying to keep a running assessment sheet is proving difficult, so I have given that to the class teacher to do' (1G SM ASS); and 'Assessment strategies were not workable with 30–31 students' (3G: SM ASS). Four teachers also made suggestions for alternative or clearer forms of assessment in one unit (Ts 8, 12, 18 ASS).

These comments are not necessarily indicative of majority views by Primary Connections teachers, but they do indicate that some teachers are quite conscious of assessment with the Primary Connections units. For a wider perspective on Primary Connections teachers' views about assessment these comments need to be integrated with the many positive comments teachers made about assessment processes that would posit, for example, that the Primary Connections assessment tasks were 'concrete' and offered innovative ways to assess students' learning[66] (and these are outlined in section 5.5). However, 'reporting' of student progress may be an issue that needs further attention, but may not be within the ambit of Primary Connections responsibilities.

64
No comments were made for the following units: WW ES1; Ww S1; WM ES1; MMat S1; PP S1; SA ES1; SZ S1; PA S2.

65
Most comments (of relevance to this section) made in the 'assessment' strengths and weaknesses section of the feedback pro forma were in ASS. An OTM teacher also suggested a clearer form of assessment.

66
Primary Connections units include a summary of various 'assessment opportunities' for each phase in the appendices of each unit.

9.6 Overall teacher assessment of unit outcomes

Elsewhere in this report (*see* Chapter 4) teachers' views about the strengths and weaknesses of Primary Connections units have been overviewed. These 'views', in part, indicated that a noticeable number of teachers thought a strength was that Primary Connections units impacted positively on students' learning. In the analysis of the *Evaluate* phase (section 5.5) examples were given of how teachers (and students) had reviewed and, to a lesser extent reflected on, students' learning. Comments indicative of the overall assessments of student learning outcomes made by teachers referred to students' enjoyment of Primary Connections units, their conceptual progress and, to a lesser extent, their development of science inquiry processes and skills[67]. It is of interest that 'enjoyment' is often mentioned by teachers as an outcome, as the lesson outcomes in Primary Connections units focus on students' SU and SIS, although an underlying premise of Primary Connections is that primary students will engage more with science as a school subject, and in their everyday lives, and this obviously has an affective element that cannot be overlooked (e.g., *see* Duit, Treagust & Widodo, 2008). This emphasises the importance in the *Evaluate* phase of Primary Connections' teachers providing time for students to reflect on their learning and the learning processes used, and for teachers to 'take on board' these reflections. This is more critical than is often appreciated, as teachers can misread the 'messages' their students are focusing on in lessons (Hopwood 2007); listening to the students' voice (here, about what is happening in classrooms) is integral to assessment.

Some overall student assessment comments about particular Primary Connections units (with italics identifying assessment foci) which emphasise the above points include:

> Students *enjoyed* this unit, especially the scientific investigations. (T12G MM)
>
> Bread making is *well understood* by students .... (T5G MM)
>
> The students *enjoyed* the unit. There was significant *growth in their awareness* of their five senses and distinction between needs and wants. They *enjoyed* collecting information about their pets at home, and all students gave a presentation to the class. It was pleasing to see the inclusion of the investigation process. The students *enjoyed* the water bottle .... (T2G SA)
>
> Kindergarten now has a *better understanding* of the weather and each of the weather terms introduced. (T14G WW)
>
> Students and teachers thoroughly *enjoyed* this unit and we all *learnt heaps*. (T6G ASS; similar for T15G)
>
> I have a range of *understandings* (which is expected). (T9G CD)
>
> The kids wrote some wonderful reflections about the unit. Most thoroughly *enjoyed learning* about change. They loved the experiments .... We used the sample questions from question 6 to write a reflection/mini report about what we had *learnt* about change. (T3 CD)
>
> The children have gained *lots in skills/ understandings* and in content. (T9G CD)

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There were some less favourable overall comments on some units as well. These are reported in sections 4.2 and 4.4. However, the focus here is on the assessment of student outcomes, not general strengths and weaknesses of implementing Primary Connections units.

'Enjoyment' is often mentioned by teachers as an outcome.

9.7 Formative assessment: *Explore*, *Explain* and *Elaborate* phases

In these three phases there were usually passing comments that referred to students' outcomes (usually understandings) related to a particular task or activity, such as 'understanding comprehensive' (T3: Ww S1 L3). Assessment processes used by teachers for formative assessment were, in general, implied to be informal and included teacher observation of students' science products and their involvement in science processes, dialogue with students and more formal teacher questioning. These formative assessment processes were integrated within the suggested Primary Connections activities for these phases. Teachers referred to their reading of student journals (which were, in some classes, regularly used in each phase [e.g., Ts 4, 7 MM]), as well as mentioning flow charts (T23: MM *Explain*), and peer review (T5: MM *Explain*)[68]. A search of these phases for formative assessment comments revealed that teachers often did refer to students' progress in conceptual understanding and, to a lesser extent, their science inquiry process and skill development.

The essence of formative assessment is exemplified in these teachers' comments from the *Explore* phase of the SM unit (italics identify the formative assessment); they refer to both SU and SIS, and it is also evident how teachers took decisions to address learning issues:

> After step 2 and 3 (children walking/running/stopping) I stopped the lesson and, as a class, drew a storyboard of a child running, and I talked about using arrows to show movement. *I did this as only one child demonstrated this understanding in Lesson 1.* I thought this was necessary knowledge before children attempted the storyboard in Lesson 2. (T5: SM L2)
>
> Used different-sized cans too, i.e. weight for class challenge. Asked children to only roll from the rolling position (i.e. cannot pickup and throw to roll—too much force hurts kids!!! And cans dent easily and don't roll when dented). Children came up with different lengths depending on force of push, *but all knew that the block moved further with a 'big push' rather than a 'small push'*. (10SM L2)
>
> *To better record student understanding I have included at the end of the lesson the sentence starter 'Today I learnt ...'. This gives a very clear indication of who understands what.* I got 'that gravity holds things onto the Earth's crust' to 'there are balloons all around the Earth.' *Very obvious who 'got it' and who didn't.* Prior to teaching session 2 I included magnet play during Friday fun session, hoping that this may help prepare students for session 2. (T5: SM L3)

9.71 Formative assessment of conceptual understandings

Typical types of formative assessment comments teachers made are included in the following extracts (the 5E phase is included to emphasise its 'formative nature' and in some extracts italics are used to similarly emphasise the nature of the formative assessment).

In relation to various Primary Connections activities/tasks:

From the MM unit:

> '... resulted in interesting ideas; children wrote own ideas in science journals to track change in scientific understanding (4MM *Explore*); '... responses and explanations were good. (6MM *Explore* L4)

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For a summary of the wide range of assessment tasks and processes used by teachers in the *Engage* and *Evaluate* phases *see* sections 5.1 and 5.5. Table 5.7 also summarises theses details. It should be noted the MM reference to peer review was the only time this assessment process was mentioned across 16 units..

From the PA unit:

Can see the beginning of understanding of plant cycle. (1 PA *Explore*)

From the SZ unit:

The before and after sketches of the worms were very telling. Most children's sketches were different from the before sketch. (T2: SZ *Explore* L2; T4 similar); '... recordings and drawings reflected their learning. (T4: SZ L2 *Explore*); 'An assessment task was to draw an ant on the computer on Kidspix and label. (T7: SZ L2 *Explore*)

From the EC unit:

The students ... could readily comprehend the role of the switch! It's been great to observe their knowledge grow and willingness to share knowledge with other classes. (3 EC L7 *Elab*)

From the OTM unit:

'Optional (Odd one out): Students found the Odd one out (100% correct), and also found something that moved the same way (less correct)' and 'Students given different coloured Post-It notes (each colour indicates way of moving—swim/fly/etc). Post-Its stuck on animal pictures on wall to show ways of moving. Students realised some animals would have more than one Post-It'. (T3: L3 OTM *Explore*)

From the PP unit:

'... Not confident students understood the pull effect of gravity properly (10 PP *Explain*); 'All students knew whether the bottle would sink or float & most students correctly completed the sentences' (1 PP Explain) and 'Children's labelled diagrams were fantastic as were their explanations—What a great assessment tool. (1 PP *Elab* L6)

From the SM unit:

'The exchanges between students using scientific language particularly, during the experiments .... *The idea of forces is beginning to gel*, particularly seen and unseen (T1: SM L4): '*Only about half the class really understood what the force arrows were representing* (T4: SM L4); 'Most enjoyed the balloon game and *did good representations* (T3: SM L3); 'Balloon game worked well, and all students were correct in their placement of arrows (T4: SM L3); '*(The role-play) was a great way to see what they understood—or* didn't *understand*—but because it was *Explain* stage we discussed it at length. (T10); 'The role-plays were a good activity and *helped students to develop some understanding*. (T11: SM)

From the WM unit:

Optional activity was a great way to focus *on what* children *had learnt*. (T10: WM *Explain*)

We put out items that were not suitable *as an evaluation task* and this created a lot of discussion about suitable materials between classmates and the whole class. (T11: WM *Elab*)

From the ASS unit:

'The children who dug up materials each week gained a better understanding of biodegradability than those who waited longer'. (T8: ASS *Explore* Lesson 2); 'Children

> loved this lesson and developed understanding of tensile' (T5 ASS *Explore* Lesson 3); 'Students developed very good understanding of technical/scientific language'. (T4: ASS *Explore* Lesson 5)

From the CD unit:

> 'Although session 2 had no "experiment" the students enjoyed it and *really developed their understandings from the movement activities*' (T8: CD *Explore*); 'We organised presentations at the end of Lesson 2, in time for our own report writing *but also to see how much the students had retained from the work so far*' (T9: CD *Explore*); and
>
> I also believe that whole sorting out process which the Changes card sort and their discussion allowed *for placement of what the students had been learning into organised understandings*. This activity was beneficial because it *organised their own concepts* and gave them the time to do it (9: CD *Explain*); Fitting together the reasons why tablets fizz and the fact they actually are doing a job *was like watching light bulbs go off*. It was very rewarding for *me!* The actual work on tablets and the variables was great, although we spent a lot of time discussing it, lots of questions and answers, lots of 'What do you think ....?' etc. The ch[ildre]n (I think) *are grasping how the differences in tablets size/shape/broken/exposed/hard etc. affect the way the tablets work and how well they work*. (9: CD *Elab*)

From the EP unit:

> 'Game went well. It is a good assessment tool for a teacher to use to gauge the knowledge that students have gained in previous lessons'. (T4: EP S3 L5; also T3); 'The students made awesome, moving models with their cut outs and wrote explanations which really showed they have pulled everything together so far. (T9 EP L3); 'Many students have developed a good understanding of the concepts of a day/year/month'. (T4: EP L4)

9.72
Formative assessment of science processes and skills

There were fewer instances of teachers commenting on student development of SIS. There is further discussion of students' use of inquiry skills in sections 7.3 and 7.5 and assessment aspects can be discerned in that discussion. Here, though, the focus is on formative assessment of SIS[69]. Separation of SU from SIS is, to some extent, superficial, as sometimes teachers have concurrently commented on both (as in T9 CD above). However, on several occasions it was possible to isolate comments that had a SIS focus. It may be noted that there were many comments about fair testing in the ASS unit. This trial unit had more lessons focusing on fair testing than several other units.

From MM unit:

> Children *successfully completed and understand fair testing* (6MM *Explore* L4); 'Children designed their own fair test using procedure from L2 as guide. Came up with similar to RS2. Was great assessment of knowledge of fair testing and procedure genre'. (4MM *Explore* L4, italics added to indicate assessment of SIS)

From SM unit:

> Only 5 *children could understand the variables grid*. Identified 3 variable (type of stapler, surface of table, friction between surfaces) .... I'm not sure the children got

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Reference to comments in the *Elaborate* phase are still included here, although Primary Connections refers to this phase as being for summative assessment of SIS. Clearly, there is overlap between these two assessment purposes.

> much out of it as it was beyond many of my students' capabilities. The writing, the graph, concept of fair test, *only 2 children were able to understand this*. (5 *Elab*)

From the SS unit:

> Graph was a great assessment tool. (T6: SS L5 *Elab*)

From the CD unit:

> Discussion and conducting experiments with variables, concept of fair test was very clear. (8 CD *Elab*)

From the MMat unit:

> Identified Literacy focuses worked well, enabling **M**aking **C**onsistent **J**udgements (MCJ)–form of assessment. (13G re LO MMat)

From the ASS unit:
'Investigation planner is well set out and easy to use, with all the information contained on the one sheet making it easy for assessment purposes' (T14G ASS Inv Sk); 'Students enjoyed example given, gives a clear understanding of how a test can be varied and variables easily identified'. (T21: ASS *Eng*); 'Reinforced fair testing as some groups did not keep tests consistent' (10 ASS *Elab* L7); 'Students really getting the idea of fair testing' (12 ASS *Explore* L3); 'explanation for fair test incredible, transferring understanding of fair test into other experiments was brilliant'. (9: ASS *Eng*)

From the EP unit (an interesting SIS):

> The solar system info organiser worked well. It tied in beautifully with teaching kids about verifying sources and cross-referencing information, and made them really think about how the first and only piece of info they read may not always be accurate. (T3: EP L5)

From the PA units:

> Children had difficulty identifying variables even after using planning Chart—I think this may have confused them. Need to do many, many investigations before children will be able to work through this process with confidence and understanding. (12 PA *Elab*)

9.73
Formative assessment from Harlen's (2009) perspective

Harlen sees formative assessment as pivotal in encouraging students' effective learning in science. The learner roles that Harlen (2009, p. 40) has identified are:

- Agreeing the standards of quality to apply in assessing their work
- Participating in peer-assessment
- Participating in self-assessment and identifying the next steps
- Reflecting on learning processes and outcomes
- Taking responsibility for working towards the goals of particular activities.

Harlen's learner roles and consequent teacher responsibilities are a useful barometer to interpret teachers' comments that imply formative assessment.

Evidence of these learner roles from this perspective indicates that some assessment windows appear to be rarely opened by Primary Connections teachers.

Only a very small number of teachers' comments could be located that implied Harlen's learner roles, except for 'students reflecting on learning processes and outcomes', which were the focus of section 5.5 (*Evaluate* phase). In that section, it was found that opportunities were provided for students to review their learning of conceptual outcomes. There were fewer mentions of students reviewing their progress in developing SIS, but, as noted in section 7.5, some teachers were aware of this dimension. Several teachers also had students reflect on their learning outcomes across a range of categories, but reflection on learning processes was far less apparent.

Teacher feedback comments did not appear to refer to learners 'agreeing (to) the standards of quality to apply in assessing their work' or 'taking responsibility for working towards the goals of particular activities', but it would be plausible to assume that as teachers assisted students to, for example, improve on their fair testing, that students started to become aware of the standards required for more rigorous fair testing; some of the examples in Chapter 7 do suggest this could be the case, but, as a generalisation, it is problematic that it would have been common across most teachers' classes. With reference to peer and self-assessment[70], they were mentioned, but only twice across 16 units; in MM, namely: 'Students peer review summaries using a comment sheet with headings "What you did well" (and) "Some suggestions"' (T5MM *Explain*), and in EC a teacher implied that 'self-evaluation' would be included: 'I am eager to use the reflection resource sheet as it allows for very constructive self evaluation (T18: EC).

On the basis of the 5E analyses and those reported in this chapter, judgements were made as to the presence of formative assessment learner roles across all 16 units. Table 9.1 indicates what these analyses suggest about the likely distribution of these roles based on teachers' feedback comments.

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Several teachers' comments implied they did encourage students to reflect on their work, but it was not clear, apart from the examples cited, that self or peer assessment was integral to the reflection, in the sense that students 'understood the goals' of their work, 'appreciated the criteria of quality that apply', judged their work against such criteria, and then decided what to do next (Harlen, 2007, p.30).

Table 9.1: Extent to which the formative assessment learner roles were explicit/ implicit in teachers' feedback comments across 16 units

Learner role	Extent
Taking responsibility for working towards the goals of particular activities	Low
Agreeing the standards of quality to apply in assessing their work	Low
Participating in self assessment and identifying their next steps	Low
Participating in peer assessment	Low
Reflecting on learning processes and outcomes	Low to Moderate*

* This is an amalgamated rating, in that reflection on outcomes was more common than on learning processes.

Meaning of extent ratings: if about 5 or more imply the role in 75% or more of the units, then Very high; 50% or more High; 25% or more Moderate; less than 25% Low.

Teacher roles in formative assessment

Teachers' roles associated with these learner roles are:

- Making provisions for the learners' roles.
- Identifying progression towards both short- and long-term goals of learning.

- Providing feedback that advises learners on how to improve or move on
- Using information about learners' progress to regulate teaching, providing the amount of challenge that promotes learning. (Harlen, 2009, p. 40)

PC FINDINGS

All students actively engaged with ideas and … with evidence across many units.

Section 9.7, together with the analyses related to the 5E model overall and the *Evaluate* phase (section 5.5), does indicate that teachers across most (and probably all) units did fulfil all these roles to varying degrees. Although this seemed to be the case, peer and self- assessment were very rarely isolated. The challenge for teachers is to think about their students' learning in science like they do in literacy and numeracy; as Fleer, Hardy, Baron & Malcolm (1995, p. 7) says: 'teaching science, in many respects, is no different from, say, the teaching of language and mathematics'. There are indications in these teachers' feedback comments that Fleer's description was becoming a reality for some.

9.8 Assessment in Primary Connections learner roles across the units

A conclusion from this chapter is that Primary Connections has enabled many teachers to engage in assessing their students' learning progress in science. This is a major development compared to a time when assessment of students' learning in science at the primary level may not have even been considered important.

Strengths from this analysis suggest that conceptual outcomes are generally well assessed using a variety of procedures, although assessment of SIS is not as obvious. Furthermore, some teachers are engaging in all forms of assessment, diagnostic, formative and summative. From the formative perspective, there do appear to be some learner roles that deserve more attention.

9.9 Implications for the implementation of Primary Connections: an assessment perspective

A summary of the findings and insights from this assessment perspective is in Chapter 12 (section 12.71). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

Chapter 10

SiS components for effective science learning: did teacher feedback suggest their presence?

10.1 Science in Schools (SiS) components for effective learning of science

The Science in Schools (SiS) project (Tytler, 2002a,b; 2003) was a major evidence-based study involving a large number of primary schools in Victoria and many participating teachers. One of its major outcomes was the identification of components for effective science learning. These components were:

- students are encouraged to actively engage with ideas and evidence;
- students are challenged to develop meaningful understandings;
- science is linked with students' lives and interests;
- students' individual learning needs and preferences are catered for;
- assessment is embedded within the science learning strategy;
- the NoS (how science works) is represented in its different aspects;
- the classroom is linked with the broader community;
- learning technologies are exploited for their learning potentialities.

(Tytler, 2002a, p. 35; 2002b, p. 9; 2003, p. 285)

10.2 Determination of the presence of SiS components

Teacher feedback in this study was analysed to determine if there was evidence of SiS *components* being present as the 5E cycle was being implemented. It would not necessarily be expected that all components would be met in every lesson sequence, but in most instances it would be preferable if they were. In using this approach it must be appreciated that learning is dependent upon many factors; that Tytler's study identified eight components reflects this truism. Furthermore, it is also accepted that the teacher has a critical influence on students' learning (e.g., *see* Tytler, 2007) and that the nature of effective teaching is very difficult to encapsulate in a series of statements. This, in part, is because describing quality teaching depends upon its context, and 'context' has multifarious interpretations, as outlined earlier in this report (*see* sections 2.55 to 2.57).

Detailed unit analyses presented in this section resulted in tables that estimated probabilities as to whether the SiS components might be present in the majority of classes that were taught each Primary Connections unit. These estimates were based on the frequency with which teachers made reference to characteristics associated with each SiS component[71]; an example is shown in Table 10.1 (16 of these tables were prepared). From these individual SiS unit tables a summary SiS table was compiled (Table 10.2). This summary table provides an indication if the SiS component was probably or possibly present (or not) in a majority of classrooms. If 'Yes' is entered in the table then this indicates most teachers' comments indicated the presence of the SiS component; if 'No' then either no comments indicated the presence or, at most, possibly one mention. The terms 'probably' and 'possibly' are used as exact numerical data are not available; 'probably' implies that the criteria are more than likely present in a majority of classes and 'possibly' implies that the criteria may still be present in a majority of classes, but it is less likely. It must be remembered that the presence of 'No' (in any form) in the table(s) does not mean the SiS component was absent; it means that teachers' comments did not refer to the component. Nevertheless, this analysis still provides avenues for further investigation.

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Also, where appropriate, analyses in earlier chapters were drawn upon, and additional searches of teachers' comments for SiS conditions. The 'degree of likelihood' that the SIS criteria were present in a majority of classes that trialled the 16 units was an informed decision based on these analyses.

10.3 Summary of SiS findings across all units

The summary table (Table 10.2) suggests that:

- Some (SiS) components were met in a majority of classes across all units, namely:
  - Students are encouraged to actively engage with ideas and evidence.
  - Students are challenged to develop meaningful understandings.
- Some components were met in a majority of classes across most units, namely:
  - Assessment is embedded within the science learning strategy.
- Some components were met in a majority of classes in a majority of units, namely:
  - Science is linked with students' lives and interests.
- Some components were met in a majority of classes, usually in a significant minority of units, namely:
  - Students' individual learning needs and preferences are catered for.
  - NoS (how science works) is represented in its different aspects.
  - The classroom is linked with the broader community.
- Learning technologies are exploited for their learning potentialities.

Table 10.1: Degree of likelihood that SiS criteria indicating conditions for effective primary science learning were present in a majority of classes that trialled the analysed Primary Connections *Push-Pull* S1 unit

SiS criterion	Present for a majority of classes (1)	Comment
Students are encouraged to actively engage with ideas and evidence	Yes (ideas) & Probably Yes (evidence)	▪ Interaction with 'ideas' in all phases ▪ 'Evidence' not as apparent but present for some teachers
Students are challenged to develop meaningful understandings	Yes	▪ Meaningful understandings implied by several teachers ▪ Occurred in most phases ▪ *Push-pull* concepts explicit at times
Science is linked with students' lives and interests	Probably No	▪ Rare to discern in comments
Students' individual learning needs and preferences are catered for	Possibly No	▪ Rarely mentioned but 'class level' and 'high achievers' mentioned
Assessment is embedded within the science learning strategy	Probably Yes	▪ Present in several phases ▪ Diagnostic only in a few cases ▪ Formative more obvious (*Explore*; *Explain*)
The NoS (how science works) is represented in its different aspects	No	▪ Direct reference to the NoS rare (e.g., test-retest)
The classroom is linked with the broader community	Possibly Yes	▪ Parents the focus in one lesson
Learning technologies are exploited for their learning potentialities	No	▪ Only mentioned by 3 teachers on 3 separate occasions (and only digital photos and video)

(Similar tables were prepared for each of the 16 analysed units)

INTERPRETATION OF THESE TABLES

1 The titles are those used in the trial Primary Connections units.
2 The 'degree of likelihood' that the SiS criteria were present in a majority of classes that trialled the analysed Primary Connections units was an informed impression based on the 5E analyses (e.g., *see* appendices 5.1 and 5.2) and additional searching of teacher comments for SiS conditions. The inferences are made on the basis of feedback comments made across a range of lessons in various phases.
3 The terms 'probably' and 'possibly' are used as exact numerical data is not available; 'probably' implies that the criteria are more than likely present in a majority of classes and 'possibly' implies that the criteria may still be present in a majority of classes, but it is less likely. Where 'yes' and 'no' are the descriptors, it does not mean that all or no teachers referred to these criteria, but that they were regularly or rarely mentioned.

Table 10.2: Degree of likelihood that SiS criteria indicating conditions for effective primary science learning were present in a majority of classes that trialled the analysed Primary Connections units

SiS criterion	*Weather in my world*	*Water works*	*Spinning in space*	*Earth's place in space*	*Staying alive*	*School-yard zoo*
Year	06	06	06	11	09	08
Students are encouraged to actively engage with ideas and evidence	Probably Yes	Yes	Probably Yes	Probably Yes	Yes	Yes
Students are challenged to develop meaningful understandings	Possibly Yes	Yes	Probably Yes	Probably Yes	Probably Yes	Yes
Science is linked with students' lives and interests	Possibly Yes	Yes	Probably No	Probably No	Possibly Yes	Yes
Students' individual learning needs and preferences are catered for*	Possibly No	Possibly Yes	Possibly No	Possibly No	Possibly No	Possibly No
Assessment is embedded within the science learning strategy	Possibly No	Possibly No	Probably Yes	Probably Yes	Possibly Yes	Probably Yes
The NoS (how science works) is represented in its different aspects	No	Possibly No	Probably No	Probably No	No	No
The classroom is linked with the broader community	No	Yes	Probably No	No	No	Probably Yes
Learning technologies are exploited for their learning potentialities	No	Possibly Yes	Probably No	Probably Yes	Possibly No	Probably Yes

* It would not be expected that teachers would include comments on this SiS component (*see* section 10.7).

Plants in action	*Marvellous micro-organisms*	*On the move*	*Push-pull*	*Smooth moves*	*Electric circuits*	*What's it made of?*	*Material matters*	*All sorts of stuff*	*Change detectives*
06	06	06	06	09	07	08	09	08	08
Yes	Yes	Yes	Yes	Yes	Yes	Probably Yes	Probably Yes	Yes	Yes
Probably Yes	Probably Yes	Yes	Yes	Probably Yes	Yes	Probably Yes	Possibly Yes	Yes	Yes
Probably Yes	Yes	Possibly Yes	Probably No	Possibly No	Possibly No	Probably No	Probably No	Probably Yes	Probably Yes
Possibly No	Possibly Yes	Possibly No	Possibly No	Possibly No	Possibly No	Probably No	No	Possibly Yes	Possibly No
Probably Yes	Yes	Possibly Yes	Probably Yes	Probably Yes	Yes	Possibly Yes	Possibly No	Yes	Yes
Probably No	Possibly No	No	No	No	Possibly Yes	Probably No	No	Probably Yes	Probably Yes
Probably Yes	Possibly Yes	No	Possibly Yes	No	Possibly No	Probably No	No	No	No
No	Probably No	No	No	No	Possibly Yes	Probably No	Probably No	Probably No	Probably Yes

In drawing these inferences it must be reiterated that teachers were not asked to indicate what happened in their classes that related to these components. The inferences are based on the content of the statements made by teachers (as described in section 3.3). Of all the components, the one that is most likely underestimated is 'Students' individual learning needs and preferences are catered for', as it is unlikely that teachers would comment on this condition within the context of the feedback pro forma. However, even meeting this component was mentioned by a number of teachers, as detailed in section 10.7.

Even though four components were not identified in a majority of units, it is still a positive finding that evidence of all components was found in statements by some teachers in a variety of units. This is because of the nature of the data collected. Having an appreciation of this background, the above findings (and the detail in this section) provide a set of different lens for those providing professional development for teachers implementing Primary Connections. Further, the examples within the various sections in this chapter could become the basis for professional development tasks as well as suggestions for teachers using Primary Connections units.

Analyses related to each of the components presented next. Assessment is not included as it was the focus of Chapter 9.

10.4 Students encouraged to actively engage with ideas and evidence

This component focuses on 'ideas' and 'evidence'. It implies that students are encouraged to express their thinking and to interact with evidence that is embedded in observations and other data sources. Students' input is expected to influence what happens in lessons, and to take some responsibility for what happens in lessons and how their learning progresses. In the following, a distinction is drawn between ideas and evidence, even though the two overlap.

10.41
Engagement with ideas

Teachers' comments clearly indicated that in each of the 16 units analysed[72] students actively engaged with ideas. There were numerous comments related to each unit to support this conclusion. An example would be students thinking about the nature of solids, liquids and gases in MMat[73]. Further, this engagement with ideas was across all phases in the various units.

Some teachers' comments that exemplify this engagement with ideas from a range of units across the primary years are outlined below.

EARLY STAGE 1

In the WM unit, the 5E analyses[74] clearly indicate that students have engaged with 'ideas', for example, their thoughts about their school environment and testing materials for how 'waterproof' they are. Some examples were students 'Had to discuss the options some people made and changed our ideas' (5T: WM *Explore*) and think 'about the effect the weather may have had on (particular) material' (T5: WM *Elab*).

72
For this SiS criterion it became obvious, after analysing more than ten units, that the criterion was being addressed. Consequently, comments from teachers are from a selected range of units.

73
This engagement is not to suggest that there were no difficulties at times, as in MMat and with the concept of forces in PP and SM.

74
Here and elsewhere, where these analyses are mentioned, further evidence that the condition has been addressed is in the relevant subsections in Chapter 5.

STAGE 1

In Ww, 'students enjoyed the water walk, became excited about spotting access points and amazed that number of points was so much greater than predictions (and this resulted in) a lot of discussion. Students (also) were very engaged with mapping points on school plan' (T3: *Explore*, parentheses added). In MMat 'students were quite involved with balloon activity, with good conversations about reasons' (T9: MMat S1 *Explain*).

In a lesson on paper helicopters in the *Push-pull* S1 unit, engagement with ideas was obvious, although use of evidence (*see* added italics) was more problematic, as in the following with teachers 4 and 5. Some relevant extracts include: 'Session 2—fantastic demonstration. Some really good comments by students' (2 PP L6); 'Word Wall going well and helicopters were very successful. All children experienced success and realised *how it is important to test and retest*. (T4; T1 similar PP L6); 'students enjoyed this (paper helicopter task). *A lot of scientific thinking and discussion*. Good diagrams' (T5: PP L6); and

> We used worms and ants for this lesson. Children wrote an explanation text explaining differences.... Watched *A Bugs Life* and children wrote explanation text about similarities between real ants and movie ants. (T5: SZ *Explain*)

STAGE 2

The 5E analyses clearly indicate that students engaged with 'ideas' in the SS unit, for example, in the mind map and role-play tasks. *Smooth moves* was also a unit where students showed thoughtful interaction with ideas:

> Brainstorming what moves in the classroom. Children came up with lots of interesting ideas. We finally reached the conclusion that *everything* with some kind of force could be moved in the classroom .... The discussion enabled some higher-order thinking skills to be used by careful questioning. (4 SM *Eng* emphasis in original)

This level of engagement with ideas was also clearly present in ASS, in which students 'really thought and learned about properties' (T1G ASS) and 'interacted well in discussions .... Knowledge, vocabulary, processes and development skills were all reinforced by examining different materials' (T21G ASS). As another teacher said:

> The best aspect of this unit was that it provided hands-on activities for the students to engage with in a meaningful way, finding out answers by testing possibilities themselves provided a real sense of ownership of their learning. (T22G ASS)

STAGE 3

As with the earlier stages, many teachers described students' strong engagement with thinking about ideas, as exemplified in: 'It's amazing where the spark created by this unit has led some 12 year old minds' (T5G: MM); 'Great lesson, students began to relax, try other ideas and were really engaged in this process' (T13: EC *Explore* L4); and: 'Students love burning candles, managed line graph well. They understand clearly that burning uses oxygen and the jar size is related to the amount of oxygen' (T5: CD *Explain=Explore*).

10.42
Engagement with evidence

'Evidence' in science was described earlier (*see* Feasey in section 7.1). Engagement with evidence, in this sense, was not mentioned or implied as often (as 'ideas' above) in teachers' feedback. In general, it was more difficult to discern. The suggested activities in some Primary Connections units had a direct focus on students thinking about evidence, while, on other occasions, teachers used special approaches that required students to turn their attention to considering the evidence in a particular context.

Units in which PC activities had an evidence focus

Two units directed students to focus on 'evidence'. In CD, the *Engage* task was a 'Mess scene' scenario in which students had to become '*Change detectives*'. In this context, they had to examine the 'evidence' and they 'got right into the scenario and really enjoyed looking at the reconstructions of the evidence' (T5: CD *Eng*). It is problematic whether students (or teachers) aligned this activity with the use of evidence as is understood in the NoS (*see* section 10.9).

In EP, Lesson 4, centred around Galileo's discoveries and his trial, provided some positive examples of engagement with evidence. Some students questioned how Galileo could have possibly been convicted. Particular teachers fully engaged their students in evidential discussion, helping them to develop 'understandings that scientists from the past are real people and their theories were based on evidence' (T7: EP Lesson 4). This approach is exemplified in:

> The boys have enjoyed discussing theories and claims of people in the historical context—a new idea for many of them. It has been a good lead for discussing the use of the internet and how to be aware that people can put claims and theories on current-day websites—sessions needed on how to trust a website—what to look for in the web address. (T8: EP L5)

Units in which teachers used special approaches to focus on evidence

In at least two units teachers used techniques that encouraged students to seek out evidence for their views or predictions. These were developing 'critical thinking.' 'Baloney detection' skills, including Sagan's (1997) Baloney detection Kit (in CD), and the well-known Predict-Observe-Explain (POE) approach (in EC as well as in other units). The former is outlined in:

> Reviewed the historic development of scientific ideas via previous work on 'What's out there' unit on space a) rocketry, b) ideas on the universe from Ptolemy to Present. We had our 'Scientist in Residence' with us for a month. Preschool to Y7 worked with her doing investigations. This helped to develop critical thinking/baloney detection of an effective scientist. We also use a 'Baloney Detection Kit', derived from idea of Carl Sagan, to assist students develop investigating and questioning skills. (T19: EC *Explore* L2)

'The boys have enjoyed discussing theories and claims of people in the historical context—a new idea for many of them. It has been a good lead for discussing the use of the internet and how to be aware that people can put claims and theories on current-day websites.'

Testing students' ideas using the POE strategy required them to look for evidence to support their predictions. Some classes 'easily and automatically used the Predict, Observe & Explain process' (T1: PP L 3), whereas others 'had difficulty comprehending the POE model. Many found the thinking way too challenging' (T5: PP L3). This approach is challenging for some first-time users, but with patience and practise, students of various ages can become familiar with its requirements (Flack, Mariniello, Osler, Saffin & Strapp, 1998).

Examples exemplifying 'evidential science practice' across primary years

These Primary Connections teachers provided examples that illustrate teachers can require students to provide reasons for their response at all levels.

EARLY STAGE 1

The youngest learners can be encouraged to provide reasons for their thinking, and this can be a stepping-stone to learning about evidence in science. In a grouping activity (about types of movement) a teacher commented: 'Excellent! Good for scientific knowledge and oral justification. Good thinking task' (4 OTM L4 *Explore*). This type of discussion, engaging with ideas/evidence, requires students to sit still, listen and share their thinking. Some teachers of very young learners found this a challenge. This type of discussion with younger learners can be assisted when the focus is on recently completed hands-on tasks or readily recalled everyday experiences (Varelas, Pappas & Rife, 2006), and is implied in: 'We made paper kites that were highly successful, and due to movement creating wind forces we were able to be more involved and have some constructive discussion' (T4: WW *Elab*).

STAGE 1

Students use of close observational evidence is apparent in classes where teachers had their students draw 'before and after sketches of the worms' and commenting that they 'were very telling. Most children's sketches were different from the before sketch' (T2G: L2 SZ; T4 similar) and: 'It was amazing how detailed the students' drawings became after using magnifying glasses to have a closer look. Some children drew the saddle and wanted to find out more about it' (T16: SZ L2).

STAGE 2

When teachers ask students to provide evidence to support their views or decisions, this can require students to engage with the concept of evidence. In the ASS unit a teacher noted, after *Explore* tasks on plastic, that their 'students were able to write *well-reasoned* expositions' about the properties and uses of plastics (T4: ASS *Explain*, italics added).

Students can be encouraged to seek evidence for their findings through scaffolded fair testing. This is implied in the following two extracts:

> Used different-sized cans too i.e., weight for class challenge. Asked children to only roll from the rolling position (i.e., cannot pickup and throw to roll … children came up with different lengths depending on force of push, but all knew that the block moved further with a 'big push' rather than a 'small push'. (T10: SM L2)
>
> The children in some groups were worried they could not measure or control the size of the push. What was a big push? What was a small push? On linking can-rolling activity with oval activity Jane (year 4) said: 'When travelling fast it is hard to stop just like when the can is travelling fast it can't stop. The can then moves the block because the block is in the way.' (T6: SM L2)

STAGE 3

In the CD unit focusing on physical and chemical changes, students appeared to apply their observational and other evidence when 'One group came up with physical/chemical changes classification themselves—I just offered the words for the headings' (T5: *Explain* CD L5) and another teacher added (for the same lesson) that it 'worked well, especially *hearing the reasons for placement* given by individual children. (6 *Explain* CD L6, italics added)

Evidence and fair testing (Elaborate and Explore phases)

In the *Elaborate* phase of most units (and the *Explore* phase of others) students engaged in investigations that often involved fair testing (also *see* sections 5.2, 5.4 and 7.33). As with the above Stage 2 examples, several teachers' comments suggested there was a focus on students' reasons for their experimental decisions and their findings. In the SS unit a teacher simply said in this regard that the students' 'investigation evidence was excellent' (T6: SS L5). This end result is also implied in the following examples:

> They liked the ice cube melting challenge and we used to critique the 'fairness' and, in particular, lack of controls and replicates in the test. (T5: *Explore* CD)
>
> As each group had different results, drew up graph for comparison, students had excellent suggestions as to how investigation could be carried out for more consistent results across class. (T4: ASS *Elab*)
>
> Great interest created by moulds—Were genuinely *interested in and predicted outcomes of (mould) experiment* (and later) .... Ran parallel experiments to help them *test their predictions*. (T19: MM *Elab*)

10.5 Students challenged to develop meaningful understandings

This component encourages teachers to help students develop deeper science understandings and to apply them across a range of contexts. This is a major goal of the 5E model. Its sequence has implicitly built into it the development of meaningful learning through its focus on the development of a key concept or understanding[75] over a series of phases, usually involving a sequence of lessons. One teacher encapsulated this principle in:

> Wonderful to be able to work in depth with just the movement of Earth and Moon, and not spread thinly over all planets. (15 SS)[76]

The development of meaningful understandings can of course occur in any of the 5E phases, but it would be anticipated to be more apparent in the *Explore* and later phases, especially the *Explain* and *Elaborate* phases. A seminal definition of meaningful understanding is 'where the learner chooses conscientiously to integrate new knowledge to knowledge that the learner possesses (p. 159, emphasis in original); it is characterised by being able to apply new knowledge to different situations to that in which it was leant' (Ausubel in Skamp, 2008, p. 49). In this sense, the *Elaborate* phase is what meaningful learning embraces—the ability to apply an idea in a new context. Each of these aspects has been explored in earlier sections in Chapter 5, especially section 5.4, and section 6.5.

75
Harlen (2009) also argues that teachers need to assist students to move from smaller to bigger ideas (*see* section 6.8 for further details).

76
This comment (T15 SS) is the essence of the 5E cycle, but was not appreciated by all teachers, some of whom felt the focus in the SS was too narrow (for a discussion of this issue *see* Chapter 5).

‘It’s amazing where the spark created by this (MM) unit has led some 12 year old minds.’

In the various Primary Connections units some teachers directly referred to students moving towards an understanding of a particular concept, such as ‘forces’, or ideas associated with it (e.g., the effect of forces), but in many teacher comments it was implied rather than stated. In the discussion of findings related to the *Explain* phase there are examples provided related to, for example, *electric circuits* (in EC S3), the direction and strength of forces (in SM S2) and physical and chemical change (in CD S3) (e.g., *see* sections 5.2, 5.3 and 5.4).

In the following are some examples of teachers referring to the development of meaningful understandings of science concepts and then science processes.

10.51
Development of meaningful understandings of concepts: examples

In several units, it was reasonable to assume that the current scientific view was the focus of student learning, even when teachers did not articulate the concept(s), for example: ‘Love the way each lesson builds on previous knowledge and reinforces learning’ (T2: SS); ‘It’s amazing where the spark created by this (MM) unit has led some 12 year old minds’ (T5G: MM); ‘This lesson was very useful, as the discussion helped to bring many students’ misconceptions to my attention, while the discussion, other students’ diagrams and explanations assisted those with misconceptions to move onto scientific explanations’ (T19: EC L4 *Explore*); ‘Students were able to identify new understandings. Many were surprised at the differences between predictions and results’ (T22: ASS *Explore* L4); ‘We used some of our learning in our class assembly PowerPoint presentation—a slide with information about Earth, Moon and Sun’ (T8: EP); and: ‘They all worked well, and the discussion during and following showed conceptual understanding’ (T6: CD *Explain* = *Explore*)

In the following, examples are provided from teachers’ comments across the primary years, and the concepts and processes are italicised in the extracts:

EARLY STAGE 1

> We made paper kites that were highly successful, and due to *movement creating wind forces* we were able to be more involved and have some constructive discussion. (T4: WW *Elab*)
>
> The whole class enjoyed this activity and most now have a good understanding of all *weather* words. (14WW *Explore*)
>
> There was significant growth in their awareness of their five senses and distinction between needs and wants. (2G SA).
>
> Students given different coloured Post-It notes (each colour indicates way of moving – swim/fly/etc). Post-Its stuck on animal pictures on wall to show *ways of moving*. (T3 Lesson 3 OTM) [Many teachers (Ts 8, 1, 9,2) indicated this concept was being developed]
>
> … The students thought about the eff*ect the weather may have had on this material*. (T5: WM *Elab*)[77]

77
Also in this unit: ‘They’re going around the yard pointing to *objects and naming the material* ’(T1; also T2; T5; T7) [Use of object and material vocabulary was also occurring (T7; T10; T11), even if this was difficult for some (T3, 5, 8, 10, 11, 12)].

STAGE 1

Explored the water *cycle* due to individuals' interest and to clarify some myths ... children did a labelled diagram for *groundwater* activity. (T1: Ww *Explore*; also Ts 6,8,11,15,17)

After we had finished the unit we happened to walk past a spider in a web. We stopped to observe—the children focused intently, observing it and commenting on *its movements*. They were really concentrating. I don't think they would have been quite so absorbed if we hadn't done the unit. (T2G SZ)

Role-play was invaluable. The students loved it and had to really think about the creatures in terms of *structure/movement* to be able to role-play creatures. (T9SZ *Eng*)

I found the children's picture of *pushes and pulls* to be more detailed than earlier lessons. (T4 SM L7 *Elab*)

L3: The children also blew up balloons and let them go—children made links with 'Push/Pull' unit GREAT UNDERSTANDING! Overall, the children really enjoyed this unit, they made references to objects, even their lunches to *solids, liquids and gases*[78]. (T11G MMAt emphasis in original)

78
In this unit, some classes had language issues: 'Most students could sort into liquids, solids, gases but none could give the term ...' (T9: MMat *Explore*)

STAGE 2

Can see the beginning of understanding of *plant cycle*. (T1: PA S1 *Explore*); All understood what the *(life) cycle* represented. (T6: PA *Eval*)

The exchanges between students using scientific language, particularly during the experiments. The idea of *forces* is beginning to gel, particularly *seen and unseen*. (1SM L4); (and also) With another class ... I did a condensed version on the carpet only in the room with a very heavy box. All had a turn to try and pull. This actually worked better (than when taught differently) and *'gravity' came into the equation because of the weight so their force arrow diagrams* were much better understood and completed. (T3: SM L4)

Excellent learning outcomes with children understanding *why different materials are used for a particular purpose*, a lot of discussion and vocab. development in each session. (T14G ASS)

The children who dug up materials each week gained a better understanding of *biodegradability* than those who waited longer (T8: ASS *Explore*); (and also) ... gained good understanding of *absorbency*. (T6: ASS *Elab*)

STAGE 3

We added an extra bottle of straight water for this. We also dissolved a Panadol tablet as well as a Berocca tablet as the results could more easily be seen. The students seemed to understand the *chemical reaction* that occurred. We also did teabags: one in hot water and one in cold water and recorded the length of time before the water was coloured. (10: CD *Explore*)[79]

79
Also in the CD unit:
'I used the cards as they were. The children did not clue into the significance of the words.... It took several goes to get the *physical and chemical changes* right. They had other ways to group them. We used the "5 why" strategy. I would have liked more time to take the steps more slowly. There were some children still not clear on the classification idea.' (T11 *Elaborate = Explain*)
'Students love burning candles, managed line graph well. They understand clearly that *burning uses oxygen and the jar size is related to the amount of oxygen*.' (T5 CD *Explain = Explore*)

10.52
Development of meaningful understandings of processes: examples

Meaningful understandings can also refer to the nature of science and an appreciation of various scientific processes and skills. Examples referring to these process understandings was not common, although teachers often referred to students using processes, and, occasionally the nature of science (for more details referring to students interaction with NoS ideas as well as the concept of evidence *see* sections 10.9 and earlier sections).

> An excellent lesson to ensure that students understand *how to test scientifically.* (T5: MM L3)
>
> An excellent activity that worked well using the tomato cans. In working on *defining a fair 'big and small' push* we did averaging for the three small pushes and then the same for the big pushes. The data was excellent to view, especially when one of the three results was very different and asking why this was so. (T8: SM L2 underlining in original; Ts 6, 10 similar)
>
> Involvement was outstanding, social skills discussed and implemented, *explanation for fair* test incredible, transferring *understanding of fair test* into other experiments was brilliant. (T9: ASS *Eng*)

10.53 Development of meaningful understandings

It is more than apparent from the above examples that students were challenged to develop meaningful understandings, and that in many instances teachers perceived they were making progress towards a deeper appreciation of many of the identified (italicised) concepts. It is reasonable to assume that the activities in Primary Connections and their sequencing using the 5E model played a part in challenging students with these concepts and understandings, as indicated by the following teacher: 'I found the children's picture of pushes and pulls to be more detailed than earlier lessons' (4 SM L7). In fact, some teachers indicated they saw the effect of students encountering sequential Primary Connections units on longer-term understandings as in: 'These children did *Push-pull* previously, so they were using terms such as push, pull and force regularly' (6SM *Eng*) (also *see* section 4.26).

Challenging concepts: teachers' contrasting views and different approaches

Examples of differing teacher approaches to specific Primary Connections activities/ tasks are described below. They refer to students learning about ideas in units in the 'Earth and beyond' and 'Energy and change' strands. As indicated earlier, teachers' views and decisions will be influenced by their context, and this is always a consideration when comparing how teachers react to similar curriculum resources.

The development of understanding is assisted by students articulating their ideas with others, including the teacher. The perceptions of teachers can sometimes sharply differ in relation to activities requiring the sharing of ideas. This is illustrated in the following comments from the EP unit, which suggest that engagement is somewhat dependent on teachers' perceptions of the role of discussion (e.g., to elicit students ideas):

> [Lesson 1] involved a lot of sitting down and listening and discussing and recording of ideas. There was a bit too much of the same type of activity and many students became restless and began to disengage. (T4: EP)
>
> Role-play [in Lesson 1] worked well, discussions about RS2 [the concept cartoon]. The whole unit so far has been enjoyable and motivating for students. Orreries worked very well, children enjoyed making them. Continual discussions about correct model from RS2 ensued through term. (T14: EP)

Some teachers considered particular lesson components were too challenging for their students, especially those 'less talented'. Although this is a real consideration, it can be dependent on teacher scaffolding, as illustrated in the following: this teacher was commenting on Lesson 2 (more teachers considered this lesson difficult compared to all the others): ‘At least there was comprehension on faces and comments the second time’ (T15: EP). Teachers also may need to make adjustments if they believe a task is too difficult, so that it suits their class: ‘We are a year 4 class, so a few activities may have to be slightly altered for their younger age’ (T8: EP)[80].

In SS a couple of teachers also considered the concepts were ‘too difficult and abstract’ (T11: SS) or too challenging (for year 4)[81] (T8: SS), yet this was not the experience of most SS teachers or findings in the literature (Skamp, 2012d). These issues may be more a function of teacher scaffolding than student understanding; in other words, as has been argued by researchers, and supported by their findings, ideas often argued to be beyond the primary years, such as an understanding of aspects of the particulate nature of matter, can be made accessible with appropriate pedagogy (Wiser & Smith, 2008).

Teachers’ pedagogical decisions may also account for the reported differences in the two sequential units about forces. In the *Push-pull* S1 unit, the representation of push and pull forces caused difficulties for three teachers (Ts 1, 3, 4, 11) and students found it challenging (Ts 2, 4), with ‘gravity’ specifically mentioned (T4), although two teachers (Ts 1, 17) reported no difficulties. Similarly, in the SM S2 unit, the direction and strength of forces, as represented by arrows, also caused difficulties for three teachers (SM Ts 4, 11) and students found it challenging (Ts 2,19,4), but other teachers (Ts 3, 4, 11) indicated that with ‘*lots* of guidance’ (T4, emphasis in original) the outcomes were positive. On balance, as considerable numbers of teachers reported success in some of the Primary Connections units that others felt were too difficult, then scaffolding advice may be the way forward, especially when research has reported that many students can interact profitably with concepts such as forces and movement of astral bodies (for examples *see* Tytler, Darby & Peterson, 2012 and Skamp, 2012d).

80
The EP S3 unit is aimed at upper primary students (AAS, 2008).

81
SS S2 was aimed at this age range.

10.6 Linking science with student lives and interests

Linking science with student lives and interests means that teachers acknowledge these in how lessons are developed and taught; they need to emphasise connections with the real world on a regular basis (Tytler, 2003, 2007). This condition also relates to teachers gaining students’ ‘situational interest’, which refers to developing current interest because of events that occur within a teaching situation; the goal is to assist in the development of students ‘personal’ (or long-term) interest in science (Krapp & Prenzel, 2011). Constructivist teaching approaches value students’ ideas and aim to use them as a focus for many activities in learning sequences, but engagement does not always follow. This component, as well as several other SiS components, highlights the importance of teachers considering ‘hot’ conceptual considerations, such as classroom context, students’ expectations and needs, their interests and other affective attributes (Duit, Treagust & Widodo, 2008).

This condition can be related to the 5E *Engage* phase purposes of ‘creating student interest and arousing curiosity’, as well as students perceiving that their ‘learning is set within a meaningful context’ (*see* sections 5.11 and 5.12). Obtaining situational interest is a constant goal for teachers and, hence, applies across all

5E stages. In this section, the 5E *Engage* phase is not revisited in detail. Here, additional data are presented to indicate whether teachers included comments that suggested this link to students' lives and interests was uppermost in their thinking. If appropriate, connections to the earlier '5E *Engage*' commentary, are made.

Some of the content in Primary Connections units would have related directly to most younger students' lives and interests, such as exploring their home gardens (SZ), and fascinating materials and substances, such as growing moulds (MM). However, teachers can take additional steps to heighten this connection. This was apparent in several units.

In the following, virtually all the comments teachers made related to this component have been included. In most units there were between one and four comments that directly referred to students' lives and interests; it was obvious where this was not the case.

10.61
Nature of content and activities

In some units, teachers made it especially clear that the Primary Connections activities, per se, caught students' attention. Examples included:

- MM S3, in which 10 teachers clearly indicated how appealing the content (e.g., fungi, mould growths, bread making) tasks were: '... it's amazing where the spark created by this unit has led some 12 year old minds' (T5G: MM). Reasons for this appeal would have included the 'scientific investigations' (Ts 12G, 19G MM) in which they could 'test and see if their predictions and logical thought processes were correct or not' (T19G MM), including trying to make bread with and without yeast and 'examine other components and how they might contribute to mould'. (T8: MM *Explore*)
- The 'Green buddies' *Engage* lesson in PA S2 (that focused on 'soft toys' travelling home with students to investigate their gardens). Nine teachers commended this lesson for its motivational aspects, several commenting that their students 'loved it'; similar comments could be included about meaningful activities set within the school grounds, as in SZ S1.
- The 'toys that move' lesson in OTM ES1 'was a great success' and 'everybody brought a toy from home' generating excitement and interest. (T6G: OTM ES1)

10.62
Science in relation to everyday experiences

Some Primary Connections units strongly developed this connection by adding (in their activities) further dimensions to the ordinary experiences of life, while in other units teachers made changes to the suggested activities in order to relate the tasks to their particular students' everyday experiences, as in 'talking about raincoats and things we wear in the rain' (T3: WM ES1 *Elab*) or to possible outside interests, such as: 'Questions were placed on edge of paper—'X-Files' to demonstrate no boundary in space' (T1: SS L1). Some further examples were:

> Talking about slipping on surfaces such as tiles at the pool. I found the ch[ildre]n were able to better understand concepts when we talked about real life experiences i.e., the pool rather than learning from the experiment (in the Primary Connections unit). (T5: SM S2 *Explore* L4)

> We turned push and pull into a transport context (T8: PP S1), all in all a good unit.
> Did this unit in conjunction with 'Parraraps' unit—*'Our Dry Continent'*—ch[ildre]n participate in science investigations and share results on line with other schools, all worked in beautifully, being *Year of the Drought*. (T17: Ww *Eng*)

In some units, such as *Smooth moves* and *Push-pull*, students' interest was readily engaged (*see* section 5.1, *Engage* phase); however, very few or no teachers made comments directly mentioning connections between these units and students' likely life experiences. Teachers, in these instances, may have assumed that this was the case (e.g., 'movement' is part of what we do).

Sometimes teachers, for the same unit, perceived this connection to everyday experiences differently. In MMat S1, although at least three teachers (Ts 2,7,11) provided positive examples linking solids, liquids and gases to students' experiences (e.g., their lunches), another asked: 'How does this unit relate to everyday experiences? Where does it fit content wise?' (T10G MMat).

Other units, in contrast to the above, strongly developed this 'real life' and/or 'student interest' connection, introducing further dimensions related to the ordinary experiences of life. Some exemplary activities/tasks in units where this was the focus of more than the usual number of teachers' comments are summarised below:

- 'Bread making' (in MM S3) was an exemplary example in which 'students loved the bread making process' (T18: MM) and could 'apply new learning (here the bread making process) in a meaningful way' (T23: MM). Opportunities to develop understanding in different directions were taken by teachers, such as making pizza dough, using different bread types, 'taking photos with microscope to see differences' (T4: MM) and 'making bread by hand (compared to bread making machine) to understand the process better' (T21 and 24 MM).
- In CD S3, classes 'talked about the smell of food, odours at home and outside—gum leaves. (T6: CD *Explore*); 'Used natural body odours to talk about gas ...' (T7: *Explore*); and ' talked about having taken "fizzy medicines" and so this experience was common to all. Fitting together the reasons why tablets fizz and the fact they actually are doing a job was like watching light bulbs go off' (T9: CD *Explain*). As one teacher said about this unit: 'There were plenty of opportunities for practical applications' (T6G: CD) and these three teachers illustrated that.
- In ASS S2, teachers related activities about properties of materials to: 'lunchtime soccer play' (T10: ASS *Eng*); activities about absorbency of paper towels, which were then connected to the purposes of 'sponges, soil drainage and absorption in different soils' (T9: ASS *Elab*); and environmental issues about plastics (T2: ASS *Explain*), with one teacher orienting the ASS assessment task to the 'World Environment Day topic of Rainforests [and the] children were asked to design a home and clothing (for such an environment) and what materials [they] would use and why' (T18: ASS *Eval*). Not all teachers identified these possibilities with one adding: 'the children needed more discussion on how it [e.g., an experiment] relates to everyday activities' (T8: *Explore* task 'See through stuff').

'Bread making was an exemplary example in which students loved the bread making process and could apply new learning in a meaningful way.'

- In *Water works* S1, a teacher used a 'rainy day to launch the unit, [and the class] sat on verandah and watched rain, then did a concept map' and then linked the lessons with the 'year of the Drought' (T17: WW *Eng*). Other teachers related the unit directly to the community where 'Our children are quite familiar with bores and pumps especially those living on farms, school uses bore water' (9 WW *Eng*).
- In MMat S1, teachers referred to 'safety icons' (T2: MMat L4), and how students 'made references to objects, even their lunches to solids, liquids and gases' (T11G MMat), as well as asking students to 'design an umbrella to test water-resistant materials. Did this lesson after watching video in Lesson 1. Follow up with children testing 5 fabrics for suitability for raincoats' (T7: MMat).

These actions by teachers no doubt assisted students to see the connections of their learning to their day-to-day experiences. Their examples provide ideas for those teachers who struggled to see 'relevance' in some units.

10.63
Linking science to family and community

Linking with students' everyday lives can be heightened by making connections with students' families and the wider community (Tytler, 2007). This can occur in many ways, and some teachers added to the Primary Connections activities when they:

Encouraged family to be involved

Examples include:

- MM S3, an 'Indian mum made chapattis and children wrote the procedure' (T14 MM) and a visiting parent made flat bread 'so that children could see the difference' (T3: MM) (both '*Explore*' phase bread making lessons);
- encouraging students 'to share their understandings with their family'… where 'it was good to apply tests and understandings in different situations' as in PP S1, which 'the children really enjoyed' (T1: PP *Elab*) and where there was 'great feedback from parents' (T17: PP *Elab*);
- Ww S1, in which an *Elaborate* task involved parents and gave 'them an idea of what is happening at school' (T3: Ww), and although return rates from homes varied and interpretations were at times incomplete, graphs still eventuated' (Ts 3, 5,15);
- MMat S1, where students 'related knowledge well from school to home' (T2g MMat S1).

Invited local people and others to engage with students

Examples included:

- MM S3, where a visiting baker made bread (T3: MM);
- an 'incursion visit from mobile animal farm' (T10: OTM ES1 *Explore*);
- 'As a rural community children brought in photos of dams and creeks and interviewed an Earth contractor about building dams' (T1: Ww *Explore*);
- 'Children participate in science investigations and share results on line with other schools' (T17: Ww *Eng*).

10.64
Teacher input with additional aids

Teachers in some units brought in additional aids or readily embraced objects brought in by students. This approach related to where students 'were at', as in the EC S3 unit where one class 'used a collection of battery-operated toys, which engaged the students straight away—Tickle me Elmo, Robots and Remote Control Cars' (T16: EC), and another teacher encouraged their students to use 'buzzers and motors' when making switches (T18: EC L7).

10.65
Teacher flexibility and willingness to follow student interest

Some topics interest students, even though direct links with their lives are not obvious. Celestial phenomena and space travel is one such content area. Teachers made connections with these interests, and some organised for students to 'follow up' ideas, as in the following examples—of interest is that these same teachers added further such positive comments in later lessons:

> Students had also seen article on the TV news about solar flares on the Sun—interesting conversation. (T8: EP L1)
>
> Students have been bringing in books from home, research from the internet, a cutting of the night sky Star Map from the newspaper. Our library Research Based Learning task has been: 'Should we send humans to Mars?' They have investigated what Mars is like, what the difficulties would be, some problems that need to be overcome, why should humans go there, what would benefits be to us, how would it affect Mars? Our design and technology large project has been to build a space station model. We watched the space shuttle Discovery's last voyage to the ISS on the IWB. (T8: EP L3)
>
> Developing understandings that scientists from the past are real people and their theories were based on evidence (and later) ... one of the students wrote out the Greek alphabet as we digressed to stars and their degrees of heat. (T5: EP L5)

Despite the obvious enthusiasm for this unit in the above comments, one teacher felt the unit's *Engage* lesson did not connect with students' lives as it was 'Too theoretical—needs to be more hands-on and related to children's personal experience and understanding at their age. Many did not see connection of information in these sessions to space concept' (T6: L1).

Similar contrasting views were found in the SS S2 unit where, for example, one teacher thought the unit provided 'flexibility to follow children's interests' (T15G), while another wanted wider scope in order to link with their students' interests: 'My children desperately wanted to learn about planets' (T18G), with another also feeling that the focus was too narrow and it should have been on the 'broader topic of space'. This issue, found in both the EP and SS units, between following students' interests and a focus on a key science idea over an extended lesson sequence is discussed further in section 4.51. For both these units this tension (expressed by some teachers) must also be balanced by realising that many other teachers referred to the interest shown by students (e.g., 'excitement about the changes in the shadows' [T11: SS L5]) and were able to follow some of those interests while still completing the Primary Connections unit; that is, for some teachers there was flexibility to follow interests and still focus on the 5E main idea.

10.66 Science as a Human Endeavour

In EP S3, the inclusion in Lesson 4 of Galileo's story did connect with students in some classes (*see* section 5.3). When students are introduced to science as a human endeavour, this can have positive outcomes in terms of raising student interest. One teacher (T8 again) added further to this dimension: 'Have met with a member of a local astronomical society who will come and talk to the class about constellations' (T8: Lesson 1). Science as a human endeavour (SHE) is also mentioned in section 10.9 (NoS). There are various dimensions of SHE that teachers could develop, and in the most recent Primary Connections units this strand to learning in science is now highlighted (e.g., *see* AAS, 2011).

10.67 Student interest and the use of ICT

There is evidence that effective use of ICT engages students' interest (e.g., *see* Murphy, 2003). Use of ICT varied across the units (*see* section 10.10), but on some occasions, teachers made direct references to its appeal, as in:

> With the Electronic Science journal, each group took turns in adding an entry into the journal. They have learnt to insert pictures and even link to videos on YouTube. Students were sharing their science with their parents before school, using the interactive whiteboard. *The children enjoyed using the technology in their lessons.* (6G: SM S2 italics added)

10.68 Units in which additional links were not mentioned

There were some units where examples of teachers taking additional initiatives to relate to this SiS component were not readily apparent. Some of these units included activities and tasks that directly caught students' attention (e.g., *Schoolyard zoo* S1) or automatically made outside links (*Plants alive* S2). Others, while still receiving various levels of overall positive teacher commentary, did not include overt examples that related directly to this component: these were *Staying alive* ES1 and WW ES1.

10.7 Catering for the individual learning needs of students

As stated in the introduction to Chapter 10, teachers would not necessarily be expected to make comments relating to this component because of the nature of the feedback pro forma. It is, therefore, not surprising that there were fewer comments relating to this aspect than any of the other SiS conditions, as shown in Table 10.2. Several teachers though did indicate that units addressed individual students' needs and preferences, and these are summarised in Table 10.3. Apart from students with special needs (e.g., ESL, deaf, Autistic spectrum disorder, H1 and diabetic), 13 teachers referred to students as individuals in a range of ways (e.g., difficulties they may have had with understanding or using a skill), and five teachers referred to groups of students, such as 'gifted', 'slower' and 'reluctant readers'. To support these categorisations examples of teachers' comments are outlined below.

Table 10.3: Catering for student needs and preferences: variety and frequency of use

a
X is the number of teachers who referred to this SIS component; Y is the total number of teachers who responded to this unit.

Unit	Teacher's (X/Y)1[a]	Students' needs or preferences (teacher)	Comments
Weather in my world ES1	1/12	ESL (12)	
Water works S1	0/16		
Spinning in space S2	0/19		
Earth's place in space S3	5/15	Individual children (4, 5, 8, 11, 12)	
What's it made of? ES1	1/12	Deaf students (1)	
Material matters S1	0/12		
All sorts of stuff S2	4/18	Individual children (12, 14); Autistic spectrum disorder children (4); H1 students (1)	Fairness of task (4, 12, 14); sign graphics (1)
Change detectives S3	1/10	Weaker students (9)	Investigation difficulties (9)
On the move ES1	1/9	Individual children (4)	
Push-pull S1	1/8	High achievers (11)	
Smooth moves S2	2/9	Slower children (1); individual children (5)	
Electric circuits S3	3/16	ESL learners (1, 2); reluctant readers (18)	
Staying alive ES1	3/9	Individuals (presentations; pets) (2, 7); deaf (5)	
Schoolyard zoo S1	0/12		
Plants in action S2	9/12	Garden buddies/home	
Marvellous micro-organisms S3	4/18	Gifted (3, 23); diabetic (21); individual (5)	

10.71
Catering for children with varying characteristics

Teachers referred to units allowing for 'diverse learning styles' (T6G: PA); having 'engaging and relevant (and a) range of activities (that) drew all students into a meaningful dialogue and allowed for the extension of gifted students' (T23G: MM) as was also reported for the PP unit, which 'was a great program for extending the high achievers' (T11G: PP).

10.72
Catering for children with special needs

Units in which teachers mentioned that students with special needs were catered for included EC, in which 'the literacy presentation in cartoon format was well received and particularly engaging for reluctant readers' (T18: EC L2); 'RS8 (was

a) good worksheet, our ESL students were able to follow this readily' (T1G Res Sheets EC); and 'RS10 (had) very good instructions for students—clear steps for ESL learners' (T2G: RS). An interesting example of catering for a child with a special need was when a class 'created (their) own packaging, due to (a) diabetic child' (T21: MM *Eng*).

10.73
Catering for specific learning needs or interests

At times, individual students were catered for or noticed. In the *Earth's place in space* unit, for example, when considering a story about Greek astronomers, a teacher noted that 'one of (their) students wrote out the Greek alphabet as we digressed to stars and their degrees of heat' (T5: EP L5). In other lessons in this unit teachers positively referred to students producing their own creations (e.g., constellations Ts 4, 5, 11, 12), but this was not always the reaction:

> Some students found it quite hard to begin their own imaginative constellation. Many joined them and then saw some kind of shape rather than imagining a shape and using the stars to make the picture more lifelike. Comments like: 'I don't know' from students who have low self-esteem and did not want to be wrong. (T4: L3)

This teacher was clearly aware of individuals' needs. A focus of the 5E model is that teachers assist individual students to (re)construct conceptions. To do that they need to be cognisant of what their students think. This is not always possible with larger classes, but an interesting case was where a teacher commented on a student who still held an intuitive view of the earth's movements in the *Explain* phase:

> One student viewed the poster—Resource Sheet 2 (the concept cartoon)—literally and commented about the person on the left who thought the Moon and Sun both circle the Earth. Even though I'd explained earlier that there were groups of people who thought this. (T8 Lesson 4)

This is a very good example of a teacher fully aware of students' individual conceptions. Whether there was time to further address this student's thinking is not known[82], but time probably would have been an issue. Across several units (*see* Appendix 4.2B) teachers felt they were pressed for time as they completed activities in the units they were implementing[83].

Other ways that teachers showed they were aware of individuals in the classes included a *Smooth moves* teacher who noted: 'only 5 children could understand the variables grid (T5: SM Elaborate)' or the teacher who commented: 'one student discovered he was very good at this'. (5 PA *Elab*)

10.74
Impact of specific teaching strategies

The use of particular teaching strategies did assist some types of learners. In *Smooth moves*, for example, the 'plays were great [and] amazed [me] at how the slower children have taken on board these quite difficult concepts' (1SM parentheses added).

In a few units, individual and personal presentations were expected. In these instances, it can be assumed that teachers were catering for their students'

82
It may have assisted this teacher if it were appreciated that many upper primary students hold onto this view (Brewer 2008) and that students' ideas are rarely modified simply by teacher telling.

83
A typical example indicating time issues is a teacher who said: '... generating ideas for group investigation was a slow process and we are now struggling with other time factors' (CD 9: *Explain* = *Explore*).

individual interests. An example was in SA, where students 'enjoyed collecting information about their pets at home, and all students gave a presentation to the class' (2G: SA) and later: 'after discussing shelter students compared their own home space and their pets and recorded their shelter and their pets" (7SA L4 *Explore*). A similar situation occurred in PA, where nine teachers referred to their individual students in the 'Green buddies' task, which was partially completed at home and then shared at school.

Student needs were sometimes catered for when students were encouraged to make decisions as to what variables they would test in fair test investigations (for some examples, *see* sections 5.4 and 7.33); these, though, would have been 'small group' needs. Carrying out fair tests will at times mean that students' predictions will be incorrect or that they are involved in testing variables that do not have the 'best' or 'biggest' effect. This, of course, is part of what fair testing (and science) is about. In the following comment, for instance, the teacher would have pointed this out: 'Session 2 clearly demonstrated [the] distinction between fair and unfair, although some children were not happy when disadvantaged by distance to run or size of container' (14: ASS *Eng*).

Sometimes teachers referred to difficulties that particular activities, strategies or tasks caused specific learners, and that the teachers needed to take action to overcome the difficulty. Some instances include: 'Too advanced and wordy for Preps, immature and with a lot of ESL' (T12: WW L1); 'Some of my weaker students floundered during this investigation and relied very heavily on those students in the group who had a better understanding' (T9: CD *Explain* = *Explore*); and with cooperative learning 'some very bright students find the constant sharing boring, (but) very good for other students to go over information' (T3G: MM, parentheses added).

10.8 Linking classrooms with the broader community

This condition encourages schools and teachers to make a variety of links with the community outside the school, both local and beyond. In doing so the relevance of science becomes more apparent, as well as how science relates to various social, cultural, economic and environmental factors. Science is not seen as a 'within school' subject (*see* e.g., Tytler, 2007).

The extent to which teachers involved the community when they implemented the Primary Connections units is shown in Table 10.4. This table indicates the nature of the various community connections, and that they included the home, various invited community members, incursions and excursions. These community connections were made in all units except for WW and CD. Interestingly, the former was a unit less favoured by some teachers, while the latter was relatively popular.

10.81
School-home links

Some of the Primary Connections units included activities that required school-home links (e.g., SA, SZ, SS), while in others, teachers took the initiative. These home links were the most commonly reported outside school connections, and they took many and varied forms.

Table 10.4: Community connections in units: variety and frequency of use

Unit	Teachers (X/Y)[a]	Community connections	Comments
Weather in my world ES1	0/12		
Water works S12[b]	6/16	Home (3, 5, 11, 15, 17); other schools (17); guests (e.g., Waterwise) 11; Excursion—dam (8)	
Spinning in space S2	3/19	Email Andy Thomas (20); parents (3, 10); visit (high school teacher) (10)	Parents—not positive (10)
Earth's place in space S3	3/15	Parents (3, 8); invited speakers (8, 12)	
What's it made of? ES1	1/12	Parents (7)	
Material matters S1	2/12	Home (2); visit from Dad (dry ice) (8)	
All sorts of stuff S2	(2)/18	Questacon biodegradable bags (5); coding on plastics (6)	
Change detectives S3	0/10		
On the move ES1	2/9	Scientist in residence (4); excursion mobile farm (10)	
Push-pull S1	2/8	Parents (1, 17)	
Smooth moves S2	1/9	Parents (6)	
Electric circuits S3	2/16	Visit—Aurora Energy Education officer (18); Energex linesman (19); scientist in residence (19)	
Staying alive ES1	4/9	Parents (5); home (pets) (2, 5, 7); ambulance station excursion connections; Myer fire (4); visit dog's home (4)	International lunch (5)
Schoolyard zoo S1	6/12	Home (3, 7, 8, 9, 10,17)	
Plants in action S2	2/12	Diverse learning styles (6); individual (5)	
Marvellous micro-organisms S3	1/18	Visiting baker & parent (3)	

a
X is the number of teachers who referred to this SIS component; Y is the total number of teachers who responded to this unit.

b
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. L6 (Investigating water use at home) and L7 (Water in other places) are reported here.

Visiting parents

Examples included a parent who made 'flat bread so that children could see the difference' (T3: MM) and a 'Dad who came in and demonstrated properties of dry ice, which was very well received' (T8: MMat L4).

Tasks set for home

The 'garden buddies' (*see* section 10.61) was an activity mentioned by nine teachers and was 'a definite success (and) improved parent school contact' (T5G: PA). Other 'home tasks' included:

- Having students collect data on water use at home (Ts 3,5,14,15 Ww). Although there were response rate issues, as one teacher said, 'still enough for a *large* graph .... (Session 2) no one said drinking, so graph was not fully accurate of home use. We had lots of washing so had to divide this category' (5 Ww *Elab*, underlining in original);
- Night viewing of stars with parents (in SS unit), which was received positively in some classes with a high completion rate (T10: SS), but a 'hassle' for another as 'stressed parents couldn't always see the moon' (T10: SS);
- In SZ, there were two resource sheets 'Information note for families' and 'Backyard safari search'. These were 'accepted well by parents' (Ts 3, 9), 'many families became involved' and 'the children went to a lot of trouble to draw, take photos or find pictures of them (backyard invertebrates)'. They made a terrific wall display for the unit' (T7; Ts 9, 10, who also mentioned classroom presentations). The 'In my backyard project' was enjoyed by all students (Ts 7, 10). As reported by one teacher, the students 'presented their findings to the class and this was also an effective comparison between animals found at school and at home' (T10). Another teacher in this unit also mentioned how students 'set up a worm viewer at home (T8: SZ L2);
- Students were asked to 'compare their own home space and their pets' and record their shelter and their pets' (T7: SA L4).

'The children were very keen to share what they already knew about pushes and pulls. They were very excited about using an electronic journal to record their results.'

School tasks related to home

Several teachers gave examples of how activities in the Primary Connections unit were related to home (as distinct from tasks set at home). Teachers had students write 'a journal where water was used at home...' (T11: Ww L2) and collect information about their pets at home and then give a presentation (T2G: SA).

Other home-school links

Occasionally, teachers reported that their students were sharing their school science with their parents. This happened with the:

- *EP unit:* 'The boys have used their models (exploring Earth, Moon and Sun movements) to explain their knowledge to others including their parents' (T8G: EP);
- *SM and PP units:* 'Students were sharing their science with their parents before school, using the interactive whiteboard. The children enjoyed using the technology in their lessons' (T6G: SM). Sharing also occurred with the PP unit (Ts 1,17) with 'great feedback from parents' (T17: PP);
- *SA unit:* 'As part of Children's Week in school we had an international lunch. Parents sent in lots of delicious food from lots of countries. This fitted in with both our celebrations and science topic' (T5: SA L3);
- *MMat unit:* Reference to the safety icon in this unit was made. 'This activity was very interesting. Children really enjoyed it and came back next day—speaking experiences from home' (T2: MMat L4).

10.82
Visiting community members

The range of community members that came to schools was quite varied and did not just involve oral presentations. These visits were invariably enjoyed by the students. Visitors included a baker who 'made bread [and gave a] great talk on yeast and gluten, children very enthusiastic' (T3: MM); staff from the Gutter Guardians project, Water Watch and a street sweeper from local council (T11: Ww); a guest speaker from high school with light boxes (10 SS); an astronomer (T12: EP L5); an Aurora Energy Education officer to talk on hydro electricity (T16: EC L1); and an Energex linesman (T18: EC L1).

10.83
Excursions and incursions

Excursions are always an event for students, especially if linked in with lesson sequences, as is the case here with the 5E model. Outside (and inside) visits included an 'excursion to Cotter dam and followed the path of water supply, kids loved this excursion' (8 Ww *Eval*); 'an incursion from a mobile animal farm' (T10: OTM L3); and:

> [A visit to] 'the Dogs' Home to explore the question 'What do dogs need to stay alive?' The education officer spoke clearly about the similarity of needs between humans and dogs. This was a powerful excursion. We completed two activities. Dogs need …. People need …. This was like a final assessment to compare with the initial tree diagram. (T4: SA L4)

10.84
Other links with the wider community

To assist student engagement with the content in various units, teachers reported that:

- their students 'participated in science investigations and shared results on-line with other schools (and) all worked in beautifully' (T17: Ww *Eng*);
- 'students e-mailed Andy Thomas aboard 'Discovery'. This initiative, although not commented on further, must have sparked interest (T2- SS L1) (cf. Skamp, 2012d);
- they had their 'Scientist in Residence' with them for a month. 'Preschool to Y7 worked with her doing investigations. This helped to develop critical thinking/baloney detection of an effective scientist' (T19: EC); a 'Scientist in Residence' also spoke to another class about the 'science of toys' (T1: L4 OTM); and
- 'Myer [store] burnt down at this time and the children were able to discuss how they used their senses to know there was a fire. (T4: L2 SA)

PC FINDINGS

Fair testing provided a ready opportunity for middle and upper primary teachers to explicitly introduce the concept of evidence.

10.9 Nature of Science (NoS) represented in its different aspects

10.91 Features of NoS

This SiS component anticipates that science will be presented to students as a human endeavour. Further, science can be characterised by various attributes as well as having social, personal and technological dimensions. Science also has its limitations.

The Nature of Science (NoS) has been characterised as follows (National Science Teachers' Association in Akerson, Buck, Donnell, Nargund-Joshi & Weiland, 2011):

> Science as tentative but robust; subjective (theory laden); culturally embedded, creative and imaginative; is based on empirical evidence; is a product of observation and inference; (and there is a) distinction between theory and law (p. 538, parentheses added).

Findings have been reported that early primary students could conceptualise 'these aspects of the NoS to a certain level, in a way that they have a better understanding of these aspects than many adults who have not received such instruction …' (Ackerson et al., p. 538).

In the following, various attributes of the NoS that were implied and, in some cases made rather more explicit, are identified in the teachers' feedback comments. It is not clear from the analysed comments whether the teachers explicitly taught aspects of the NoS to which their comments alluded.

There were some units in which NoS characteristics did not appear to be present. In these units[84], there were comments about some science inquiry skills but they did not imply NoS was in any way suggested or explicit.

84
The units were *On the move* ES1; *Staying alive* ES1; *Schoolyard zoo* S1; and *Material matters* S1

10.92 Implied NoS attributes within teacher comments

The NoS attribute 'is based on empirical evidence' (e.g., taking and recording observations, noting investigation evidence, formulating explanations consistent with the available data) and was inherent in many teachers' comments across various units: *see* section 7, which indicates the wide range of SIS that students used in a wide variety of activities. Many units had a focus on fair testing (e.g., ASS Ts 5, 11, 14, 18, 21, 22), which epitomises the empirical aspect of how science works. Teachers, though, did not explicitly state that this was a NoS outcome they were emphasising with students. Typical teacher comments in the ASS unit were:

> Fair testing is a difficult concept, but was good and very important to include. (11: ASS S2)
>
> … transferring understanding of fair test into other experiments was brilliant. (T9: ASS S2 *Eng*)
>
> Session 2 clearly demonstrated (the) distinction between fair and unfair, although some children were not happy when disadvantaged by distance to run or size of container. (14: ASS *Eng*)

An example of a comment that was different to the norm (i.e., mainly mentioning observing, recording, fair testing) would be where teachers referred to further characteristics of empirical science, such as students' 'investigation evidence was excellent' (T6: SS S2).

Interestingly, two WM ES1 teachers referred to their younger students enjoying being called or seeing themselves as 'scientists'. It is problematic as to what the teachers meant; for one it was a suggestion in the *Engage* phase (it might be assumed that the teacher (T10) referred to students making observations), while the other teacher's comment was in the *Elaborate* phase and, hence, may be embracing a wider view of the empirical nature of science:

> The children loved being called 'scientists'. (T10: WM ES1 *Eng*)
>
> The kids were excited about doing things like scientists do and doing experiments. (T1: WM ES1 *Elab*)

10.93
NoS attributes more explicit in teacher comments

Examples that illustrate a range of NoS attributes are discussed below. Italics are used to isolate where the NoS is apparent.

Empirical Nature of Science

There were some comments that indicated teachers' awareness of the NoS. This was also present with the youngest learners, as in:

> … meanings of words, word origins and generated spelling tasks, students thought this a baby game initially but attitude changed *as they became aware of senses and science*. (T5: ASS S2 *Eng*)

At times the NoS was clearly apparent in the teachers' minds and may have been made explicit to their students; examples across various primary stage levels where this occurred were:

Stage 1

> All children experienced success and *realised how it is important to test and retest*. (T4: PP S1 L6)

Stage 2

> As each group had different results, drew up graph for comparison, students had excellent suggestions as to *how investigation could be carried out for more consistent results* across class. (T4: ASS S2 *Elab*)
>
> An excellent activity that worked well using the tomato cans. In working on defining a fair 'big and small' push we did averaging for the three small pushes and then the same for the big pushes. The data was excellent to view, especially when one of the three results was very different and asking why this was so … (and later) some used a blackboard ruler like a pool cue and pulled back a certain number of cm in an attempt to define small and large pushes. Most did it successfully on the width of the table simply by pushing. (8: SM S2 L2)

Stage 3

> … Session 2 took a huge and variable amount of salt. Students took the measuring, stirring and checking to see if it had dissolved very seriously but lost it after 30 odd measures …. *Gave good discussion on errors, particularly process, measurement and observation classification.* (5: CD S3 *Explore* L3)
>
> Trying to explain *why their results did not fit exactly to the graph, even after doing repeat trials and averaging them.* (1: CD S3 *Explain = Explore*)
>
> They liked the ice cube melting challenge and *we used to critique the 'fairness' and in particular lack of controls and replicates in the test.* (5: CD *Eng*)
>
> This was a great lesson … it really cemented the concept of a fair test and was thoroughly enjoyed by *the students who felt like 'real scientists' conducting real research.* (T8: CD S3 *Elab*)
>
> Some of the students found this activity a little frustrating when it didn't light up straight away, then after a long time and still no light the frustration level increased dramatically among most students. Students assisted [by] me [were] motivated to try again. Some students were disappointed by not being successful *but that's science and to try something different*! (3: EC S3 L6)
>
> Allowed children to choose own variables, would have been a good idea except that students didn't get the idea of only changing one thing …. *Recorded their experiments and mixed results showed that they can only change one thing.* (T17: MM S3)

All these comments are referring to some of the discursive practices of science. As previously noted, it is problematic whether the teacher explicitly taught their students that these are NoS features.

Appreciating the nature of 'evidence' in science

The concept of 'evidence' has been described in section 7.1 (*see* Feasey, 2012). In the following, a teacher has, with the assistance of a 'scientist in residence', honed in on this feature of science:

> Reviewed the historic development of scientific ideas via previous work on 'What's out there' unit on space a) rocketry, b) ideas on the universe from Ptolemy to Present. We had our 'Scientist in Residence' with us for a month. Preschool to Y7 worked with her doing investigations. This helped to develop *critical thinking/baloney detection of an effective scientist.* We also use a 'Balony Detection Kit', derived from idea of Carl Sagan, to assist students develop investigating and questioning skills. Students devised own timelines either by hand or electronically. (T19: EC Lesson 2)

'This was a great lesson … it really cemented the concept of a fair test and was thoroughly enjoyed by *the students who felt like 'real scientists' conducting real research.'*

Reporting 'scientifically'

Several teachers commented how students started to appreciate that scientific reporting was different to writing in other subjects. In an early primary unit, it was stated that students 'are beginning to understand that [science journals] are different to story writing (not to include who partner was or who had first turn); also drawing clear diagrams with labels and arrows' (T13G: Ww S1).

In some stage 2 units teachers commented: 'There has been a good balance of activity and scientific reporting' (T13G: ASS S2), and when observing daily growth of their plants, '[journal] writing improved from one day to the next. [The students] learnt how to make real scientific observations using real scientific language' (T7G: PA S2). In this plant growth unit (PA: S2) one teacher introduced 'scientific drawing criteria' in the *Explore* stage, and then later in the *Elaborate* stage added: 'We simply reviewed our previously covered criteria for scientific drawing and applied them to drawing a flower' (T13: PA S2). This apparent motivation of students to write could be related to them having a purpose for their writing, rather than, for example, note taking (cf. Logan & Skamp, 2008).

Science understandings as a human construction

The CD S3 *Explain* phase implies that teachers indicate that classification systems are human constructions (AAS, 2009). This was apparent in a couple of instances (Ts 3, 9), especially as in: 'The discussions around why we categorise were amongst our best of the unit' (T9: CD *Explain*). However, there were also teacher comments that may imply that appreciation of this idea was not present (i.e., particular 'classifications' had to be arrived at by the students), for example:

> It took several goes to get the physical and chemical changes right. They had other ways to group them. We used the '5 why' strategy. I would have liked more time to take the steps more slowly. There were some children still not clear on the classification idea. (T1: CD S3 *Explain*)

An appreciation that scientific knowledge is a human construction is not always readily appreciated by teachers. In EC S3, one teacher commented:

> Step 11 (Why do some materials allow electrical energy to pass through…?) The answer is not really an explanation, just a statement of fact …. (1: EC S3 L6 *Elab*)

An appreciation of the nature of explanations in science, for example, the 'why' in this extract relating to a theory of why a circuit works with some materials and not others, is different to the observation that the circuit 'works' with some materials and not others. This is not always apparent to many people.

Limitations of scientific understandings

The following teacher implied that this attribute of science was discussed with students when it was stated: 'Step 12 (Ideas about improvements to investigations). A very useful inclusion linked to scientific process. It is interesting *how rapidly children generalise*' (19EC: L6 italics added).

Mental and physical models and testing them

'Scientific inquiry … in … simple terms involves not only the use of skills relating to the interpretation of relevant evidence, but [also] the development of models of how the natural world works …' (Harlen, 2009, p.38). Students do have their own 'mental' models of how the world works (e.g., what happens when something dissolves; why we have night and day), but often they are not encouraged to offer their 'models' for what they are observing and testing; teachers sometimes do not engage their students at a level beyond observing and predicting. In some of these Primary Connections units 'models' were mentioned. One CD teacher referred to the notion of a 'model' to help students think about what happens when materials and/or substances interact:

> I also included polystyrene balls in see-through cylinders placed on speaker. Turn volume up and particles vibrate more. Talked about this as a model. (T7: CD L2 *Explore*)

Apart from the above, there were two other units which especially provided opportunities for teachers to emphasise the importance of models in explaining phenomena. Parts of EC S3 were referred to as a 'good introduction to scientific representations and diagrams' (12 L4 EC), which were 'very new concepts for the students [who] enjoyed the idea of representing the components' (17 L4 EC). In the role-play of an electrical circuit two teachers (EC S3 Ts 17, 19) stressed how the 'limitations of role-play' were an important aspect for discussion; this is a feature of using models with learners that is strongly advocated to assist in student understanding of science ideas, but also to explicitly align it with how science works (*see* a discussion on the use of models with primary students in Skamp, 2012b,c,d).

The EP S3 lesson sequence was underpinned by a related facet of the nature of science, namely, testing claims (to explain a phenomenon) through the use of (mental and physical) models. As discussed elsewhere (e.g., *see* section 5.41), this was appreciated by (probably) a minority of teachers but not by others. Helping students to see the development of mental models (here, how Galileo explained his celestial observations by a revised model of the movement of the Sun, Earth and Moon) as a human endeavour (cf. Olson's [2008] description of science as a creative human endeavour) did assist some students to think more deeply about this attribute of science. The *Explain* phase in EP (L4) seemed the most effective in modelling the NoS:

> Students beginning to understand the need for evidence before something can be proven. (T3: EP L4)
>
> Developing understandings that scientists from the past are real people and their theories were based on evidence. (T7: EP L4)

The following suggests that some students in this EP unit have been able to apply their learning about this aspect of the NoS:

> The boys have enjoyed discussing theories and claims of people in the historical context—a new idea for many of them. It has been a good lead for discussing the use of the internet and how to be aware that people can put claims and theories on current-day websites. (T8: EP S3 Lesson 5)

10.94
Some implications of these findings

With scientific investigations being a focus in the *Explore* and even more so in the *Elaborate* phase, it would be appropriate to illustrate how NoS attributes can be made explicit in these lessons as additional outcomes in Primary Connections units: for suggestions *see* Akerson et al. (2011). A related consideration is to help teachers develop a mindset in which they see themselves and their students as part of a scientific learning community (or a community of (science) practice) that aims to exemplify the discursive practices of science (Harris & Rooks, 2011). These practices are also embedded in interpretations of scientific literacy; becoming more scientifically literate is now agreed to be the main goal of science education (Murcia, 2009) and underpins the aims of Primary Connections (Hackling & Prain, 2005).

What is encouraging is that most of the Primary Connections teachers' comments identified in this section relate to NoS attributes and, hence, could be assisting students to engage in a wider range of the discursive practices of science. The task is to firstly ensure teachers are aware of the possibilities, and then for teachers to make students aware of NoS characteristics by being explicit at appropriate times.

Within the analysed units there were many opportunities where teachers could practise the above suggestions. In MM, for example, there are several fair testing investigations, and some of them open investigations (*see* section 7.33)—teachers could easily be talking about NoS attributes as they interact with their students in small groups and as a whole class. Further, in professional development workshops, teachers could pose scenarios based on extracts from this section and/or elsewhere in this report and be challenged to offer ways they could engage students in discussion about aspects of the NoS; for example, one teacher saw an investigation as a weakness because the students 'had a wide range of results—skewed the graphs somewhat' (T4G: SM S2). Questions could be asked as to what could teachers do in a situation like this (apart from suggesting that the tests be repeated)?

From the introduction to this section it is apparent that some attributes of the NoS, for example, being tentative, have not surfaced in teachers' comments. They may need to be more emphatically stressed with Primary Connections teachers.

10.10 Learning technologies exploited for learning potentialities

10.101 Mentions of use of ICT across Primary Connections units

Information and Communication Technology (ICT) has been shown to improve motivation in primary science and, if used strategically, can assist in the learning of science ideas and processes (e.g., *see* Harlen, 1999; Murcia, 2010; Songer 2007). In conjunction with the 5E model Chessin and Moore (2004) have labelled ICT the '6th E'. The extent to which teachers are aware of its value across all the primary years, including the very early grades, is unclear. There are numerous ways that ICT can be used, but often, its potential has not been exploited, as with the Interactive White Board (Beauchamp & Parkinson, 2005).

The use of ICT by teachers across the 16 units varied considerably from no reports in WW ES1 and PA S2 through to four or more teachers mentioning their use in EP, CD, MM and SZ (*see* Table 10.5). The nature of the data collection does not mean that relationships can be drawn. However, with this sample, more teachers did mention ICT in the upper primary years. There could be several reasons for this, such as the content of the units (for example, a 'space topic' invites ICT use) and the variation in sample numbers (i.e., number of teachers responding) across units.

Table 10.5: Learning technologies in units: variety and frequency of use

Unit	Teachers	ICT type	Comments
Change detectives S3	5/10	Use of digital camera (4, 6), the interactive whiteboard/ smartboard (3, 4, 8), Learning objects (5), interactive/moving diagrams (8), PowerPoint (5)	
Earth's place in space S3	5/15	PowerPoint (students) (4); IWB (13); YouTube (2,8,11); Websites (e.g., Stellarium) (11)	Difficulty in accessing websites (T1; T2; T5; T6; T8)
Schoolyard zoo S1	4/12	Website (3); Programs: Kids pix (5), Kidspiration (3, 7); Computer microscope (1); Smartboard (5, 7)	Learning Federation site (3); Use with mind maps (7); to draw snails (7)A teacher commented: Need greater use of technology in this unit (17G SS)
Marvellous micro-organisms S3	4/18	Word program (5) Hand held scanning probe microscope with computer interface (5); websites (24); Flex camera (7); digital camera (23)	Students electronic science journal (5); sources of information (24); Flex camera micro-organisms (7)
Push-pull S1	3/8	Digital photos (1, 4) videotape (5)	Videotaped presentations (5)
On the move ES1	3/9	IWB (7); digital photos (5); KidPix 4 program (1)	Scanned pictures for IWB (7); KidPix 4 to show things move (1)
Water works S1[a]	3/16	Computer use (4) Website (11); Programs: Publisher (11); Paint (12)	CSIRO site water cycle (11); newspaper evaluation (11, 12)
Electric circuits S3	3/16	Kids Pix and Inspiration Programs; diagram on the internet, PPT presentation (1); internet (16, 19); PP animation (6)	Internet for information (1, 16, 19)
Spinning in space S2	3/19	Mind-map (2,12) Kidsphere (12); Website (3)	
Staying alive ES1	2/9	Smartboard/IWB (5,7)	
What's it made of? ES1	2/12	IWB (1); Google Earth (5)	

a
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. L6 (Investigating water use at home) and L7 (Water in other places) are reported here.

Material matters S1	2/12	Digital cameras (1, 5); Kidspiration; BBC clips (5)	TWLH Kidspiration (5)
Smooth moves S2	2/9	YouTube (6) Electronic journal (EJ) (6) Engineering Interact website (8)	EJ with videos, pictures, links (6); Engineering Interact website to formalise our language. (8SM)
All sorts of stuff S2	2/18	Website (11); Digital camera (5)	BBC Website for PMI (11)
Weather in my world ES1	0/12		
Plants in action S2	0/12		

The types of ICT accessed varied considerably and are also shown in Table 10.5. In some instances, the ICT type was mentioned in Primary Connections units. There were many examples, though, of teachers taking initiatives with the selection and use of ICT. Of interest are the instances where computer attachments have been used, such as a scanning probe microscope (T5 MM) and the regular use of digital cameras. As stated above, it is mainly the way ICT is pedagogically employed that is of most importance.

10.102
Examples of ICT contexts and use

To provide a sense of the contexts in which ICT was used and (where mentioned) its perceived impac, a brief summary is provided. A more extended and novel example precedes the summary.

Electronic journal: a most positive impact on students

A SM teacher provided several comments about her students' use of an electronic journal, and also indicated her ease with ICT:

> With the Electronic Science journal each group took turns in adding an entry into the journal. They have learnt to insert pictures and even link to videos on YouTube. Students were sharing their science with their parents before school, using the interactive whiteboard. The children enjoyed using the technology in their lessons. (T6G: SM)
>
> The children were very keen to share what they already knew about pushes and pulls. They were very excited about using an electronic journal to record their results. (T6: SM *Eng*)
>
> I found that my children needed more visual examples and so I found some YouTube videos to assist. (T6G: *Eng*)

Only one other teacher briefly referred to using an electronic journal (5G: MM).

Some examples of ICT use

A limited selection of fairly common, and not so common, reported uses are listed.

- In OTM ES1, scanned animal pictures were used on the IWB, and digital photos showed fair testing procedures for later discussion; also, a teacher used the 'KidPix 4 program to make a slide depicting things that roll and slide' (T1: OTM *Elab*).
- The IWB was used in SA to develop a concept map and 'to adapt the information wheel and add small pictures representing the senses' (T5: Sa L7).
- In PP, two teachers used digital cameras. As part of the *Evaluate* phase, a teacher videotaped students' presentations (T5: PP).
- In SZ, a teacher reported: 'We were able to view an earthworm under our computer microscope as well' (T1: L2); other teachers used Kidspiration to draw snails (T3) and to 'make (an) ideas map' (T7: SZ). (This program was also referred to for the TWLH chart in MMat.) A more novel ICT applications was when a SZ teacher used various 'techniques (animation, computer graphics) to give animals human traits to help (their students) understand how they live' (10: SZ *Explain*);
- In EC, teachers mainly referred to internet sites where ideas, diagrams, historical information were obtained for PowerPoint presentations, glossaries and personal interest. Animation was also mentioned.
- A hand-held scanning probe microscope with computer interface was usefully employed in the MM unit (T5G: MM), as well as 'a flex camera to examine structure, which was a great learning experience' (T7: MM). Another teacher had 'daily observations recorded with digital photos and text' (T23: MM *Eval*).
- The wider usage of ICT in the CD unit is shown in Table 10.5. Some specific contexts were:

> 'Each group took digital photos for later use and comparison—a memory cue for use with reports done at a later date' (T6: Eng CD); a teacher '... used some 'learning objects' on [the] smart board which also demonstrated behaviour of particles and change of state' (T5, *Explore* L2; T8 similar); and another reported doing the explain activity 'on [the] Interactive white board [and it] was brilliant' (T8: *Explain*), while one teacher 'scanned the tablet investigation planner and put on interactive whiteboard—great!' (T3: *Elab*)

10.103
Other comments about ICT use reported by teachers

In the *Earth's place in space* S3 unit, there were mixed feelings about including ICT in the sequence. Most teachers who successfully downloaded sites (e.g., Stellarium) and/or accessed various internet sites found they engaged students, as did those teachers who accessed ICT resources not mentioned in the unit, such as YouTube (Ts 2, 8, 11):

> Students also researched a chosen planet and put facts about it in a PowerPoint display and presented it to the class. The headings were Classification, Position, Size, other interesting facts. The PowerPoint presentation allowed students who are advanced to pursue their interests and discover more about the solar system/planets using the internet as a research tool. (T4: EP)

Occasionally, some teachers found recommended Primary Connections sites were not helpful (as in EP). Also, a significant number of teachers reported technical difficulties (e.g., with downloading or use of sites with the IWB); for example, in response to a question about 'equipment' five teachers (1,2,5,6,8) reported ICT difficulties.

Of interest is that in the other 'Earth and beyond' unit ICT appeared to receive less usage. The SS unit was prepared in 2005, while the *Earth's place in space* unit, which showed a substantive increase in references to ICT, was prepared in 2011.

10.11 Implications for the implementation of Primary Connections: SiS components

A summary of the findings and insights from considering these SiS components is in Chapter 12 (section 12.72). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

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…the potential of Primary Connections units to link with other curriculum areas was also very positively received.

Chapter 11

Primary Connections: other implementation issues arising from analyses of teacher feedback

Introduction

Apart from deductive analyses of the Primary Connections teachers' feedback comments using the 5E purposes, Harlen's (2009) learner roles and the SiS components (Ttyler, 2003), the data were inductively analysed for any other relevant issues that may assist in the interpretation of these teachers' implementation of Primary Connections units (*see* Chapter 3). A range of issues emerged which is discussed in the following sections.

11.1 Teacher beliefs and the implementation of Primary Connections units

Many studies (e.g., Fetters, Czerniak, Fish & Shawberry, 2002) have argued that teachers' beliefs influence their practice and how they interpret and implement curriculum reforms. Aspects of their practice that may be influenced are their perceptions of the subjects they teach, here science, how such subjects are taught and how students learn in that subject (*see* section 2.53). Teachers in their feedback comments made reference to each of these areas.

11.11
Teacher beliefs about science

Teachers' references to NoS attributes

Teachers' views about NOS are sometimes implicit in their comments. These have been outlined in sections 10.9 and 11.21; for example:

> Some of the students found this activity a little frustrating when it didn't light up straight away, then after a long time and still no light the frustration level increased dramatically among most students. Students assisted me with my task, (this) motivated them to try again. Some students were disappointed by not being successful, *but that's science and to try something different*! (T3: EC L6 *Elab*)

The question here is did the teacher make 'but that's science' explicit. The following teacher may have made the implied attribute of science explicit in that they (probably) discouraged their students from generalising (and said why): 'It is interesting how rapidly children generalise'. (T19: EC L6)

The difficulty of some concepts related to the nature of science are shown in the following—the first suggests the teacher (T6) misunderstands the nature of a 'model' in science, while the second (T3) questions what is the content of scientific inquiry, perhaps not envisaging how such an investigation could lead to asking students 'why' (after testing and other exploratory talk), and even encouraging these young learners to offer their 'models' of what is happening to the water when it makes contact with different fabric.

> Had children construct word loops as a team domino activity. Most teams found it challenging and therefore time consuming. Couldn't see that it would work as a class activity—you would need a huge space .... *Don't really understand why this is a model of a circuit. I can see that it is a model of a torch but to me it seems to be a fully functioning circuit—no 'model' about it.* (T6: EC S3 *Eval* L8 italics added)
>
> Is this a scientific enquiry? What happens to things when they get wet? (T3: WM ES1 *Elab*).

Teachers' appreciation of issues in empirical investigations

A NoS attribute is 'science is based on empirical evidence' (*see* section 10.9). This characteristic is a fundamental building block of Primary Connections' focus on 'investigation'. Teachers (and their students) at times showed a real awareness of issues that arise in fair testing. These are positive teacher comments, in that teachers and students are focusing on the difficulties and challenges of fair testing. The pedagogical issue is how teachers react to these situations in discussions with their students. The following refers to testing the property of materials (comments in square parentheses indicate different aspects of completing an empirical investigation):

> Step 10: Ranking for hardness should match Moh's scale (T7: ASS) [Seeking comparisons with existing classifications to add credibility to findings].
>
> Would mark be a better word than 'scratch' as scratch tends to indicate dragging rather than hitting (T10: ASS) [Appreciation of the nature of the dependent variable and, hence, the significance of the terms used (a similar example is reported in Skamp, 2012b)].

> Students were not too happy about being restricted to one hit! (T12: ASS) [Helping students appreciate the significance of choice of values for a variable is a investigation planning decision (Harlen, 2003)].
>
> Wording was confusing to students who wanted to record whether material dented or scratched or both; brick scratched but did not dent. (T14: ASS) [As above]

In another unit:

> Problems arose when doing measurement of magnet over a distance. The different objects had different amounts of friction, hence, observations were skewed. The question is irrespective of a magnetic metal object. Does the magnet always act with the same force at the same distance from any of the objects?? (T7: SM S2 *Elab*)

Teachers appreciating these aspects of empirical investigations suggest that they are encouraging students to aim for rigour in their science inquiry.

Teachers' references to 'scientific' characteristics of lesson components

On other occasions, teachers made related types of comments, which suggest they have certain beliefs about what science means:

> Students enjoyed this. A lot of *scientific thinking and discussion*. Good diagrams. (T 5PP: S1 L6 *Elab* [about helicopter flight], italics added)
>
> I set them the task in their teams of competing with each other to move an eraser the furthest, then to figure out how to make it go further. They could then try out different-sized rubber bands. The *scientific ideas and discussions* that came out of this far excelled any my class had when trying to complete the lesson as set out in this trial unit. One group began inventing games (knocking counters into a container etc.), which sparked conversations about different games involving these forces. We all felt very satisfied after this. (T3: SM S2 *Elab* italics added)

What teachers mean when they refer to 'scientific' thinking and discussion and even 'scientific' ideas would be illuminating. These teachers clearly distinguish different types of 'thinking' and 'discussion' and, hence, expect that from their students (*see*, e.g., Feasey, 2012). Again, the teachers' perceptions of 'scientific' in these contexts becomes important[85].

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Issues posed, such as this one, could be the focus of professional development workshops.

Students' views about science: how teachers react

It is reasonable to assume that many primary students expect science to always be exciting and produce interesting and fascinating changes: it is what the media and other outlets portray (e.g., books by Dr. Karl Kruszelnicki). Yet teachers have a responsibility to engage students with what the evidence indicates and that, for example, no change is also an important result:

> I think they took it personally, they would tip the materials in together and then nothing was seen to happen. By the same token, they raved about the reactions that did occur and they would replay it for anyone that went by, 'I did this, and then this and it began bubbling etc. ...' They were quite excited. *It was hard slog getting the children to at least accept that sometimes no reaction is just as much information as if the bottles had blown up.* (T9: CD S3 italics added)

For Stage 3 students an appreciation of these types of results can be engendered. It may not be as simple for younger learners, whose attention may be dependent upon observing change (Chaille & Britain, 2003).

There are ways teachers can challenge students' views about what is involved in learning science, and that the 'learning' is engaging for primary students. Role-play is one approach that worked well in several units:

> I think they liked a different approach—it was science but we were doing drama! (T9: CD S3 *Explore*)

This was supported by another teacher with the same unit (CD):

> Drama of particle theory popular. We did in whole class, small groups and used some Learning Objects on smart board, which also demonstrated behaviour of particles and change of state. Drama gets message across to kids who struggled with abstract ideas and, likewise, Learning Objects did same. (T5: CD S3 *Eng*)

Apart from helping students appreciate that not all science is associated with empirical investigation, teachers can use such approaches to assist students in seeing that science involves creative thinking, for example, in formulating mental models to explain behaviour (which, in some contexts, can be shown through kinaesthetic simulation). Furthermore, teachers can be explicit and say to students that scientists also build and act out their mental models, so that the role-play takes on an additional (NoS) dimension.

11.12
Teacher references to, and beliefs about, scientists

At other times, teachers' remarks alluded to how science may be perceived. On a few occasions, teachers said their (ES1 through to S3) students 'felt' like scientists.

> Children responded well to the roles—felt like real scientists (17G: SS S2).
>
> We called the person watching the 'scientist'—children loved this and look it very seriously. (T1: OTM ES1 L2 *Eng*)
>
> This lesson was simple but effective. The kids were excited about doing things like scientists do and doing experiments. Worked really well. (T1: WM ES1)
>
> Children worked with a partner and enjoyed being scientists. (T4: WM ES1)
>
> We used a scientists' chat board where 'junior scientific investigators' pinned notes about their latest electrifying ideas, discoveries and questions. (T19G: EC S3)
>
> This was a great lesson ... it really cemented the concept of a fair test and was thoroughly enjoyed by the students who felt like 'real scientists' conducting real research. (T8: CD S3 *Elab*)

Teachers' interpretations of what it means to think and behave like *real* scientists is problematic, but Ucar (2011) reported that preservice teachers still held some stereotypical views on graduation. Teachers must ensure that stereotypical images of scientists are avoided. The opportunity that presents itself in these classrooms is for teachers, with their students, to engender the sense of a community of (science) practice (Harris & Rooks, 2010; Scott, Asoko & Leach, 2007). Pervasive management (Harris & Rooks, 2010) could guide the teacher's mindset where a community of (science) practice ethos is embryonic but the teacher wants it to become commonplace.

How one teacher saw real scientists in expressed in:

> Faces belittled the resource sheet. Real scientists would not use these. (T9: ASS S2 *Eval*)

The significance of students (and teachers) seeing science as practised by real people and that they can also be scientists is now recognised with the inclusion of 'Science as a Human Endeavour' (SHE) in the Australian Curriculum: Science (ACARA 2011). Of course it will be influenced by how *teachers* see scientists; hence it is important that they have a contemporary view of a scientist. The comment by the above teacher (T9) could have positive or negative effects, depending upon how the teacher handled the context of the interchange with their students.

A focus on scientists as real people faced with real-life situations was brought out further in some units that referred to scientists from the past (e.g., Galileo) and discussing the ways their theories were accepted and/or rejected:

> Developing understandings that scientists from the past are real people and their theories were based on evidence. (T17: EP *Explain*)
>
> Learning about Galileo—the students were fascinated, and appalled by the fact that somebody could be jailed for expressing an opinion—especially as it was true. They became quite obsessed with the injustice of it and it re-ignited their enthusiasm for the unit. (T9: EP S2 *Explain*)

These teachers appeared to be focusing on key elements of SHE and the NoS.

11.13
Teacher beliefs about appropriate content and concepts in science

Teachers' and students' beliefs about appropriate content can be quite different

Teachers' beliefs about appropriate content can sometimes be astray. Teachers' perceptions about particular science content in Primary Connections could influence whether they teach a unit or not. It may be useful to inform teachers of other teachers' positive outcomes:

> Very easy to work other KLAs into this unit. Thought this was going to be boring but the children really responded to all the activities. (T8G: Ww) [Topic was 'water', its uses, sources, etc.]
>
> I was quite surprised how interested the children were in this unit. Water is a very real and relevant topic to the children .... *Engage* and *Explore* lessons trialled were very appropriate to my class. (T9G: Ww)
>
> I was unprepared for the students' enthusiasm, had to remind children of safety issues when 2 of them climbed on bubblers to investigate pipes. (T5: Ww *Explore* L2)
>
> Initially thought this wouldn't be too exciting but the children found so much more than I thought they would—bodies, clouds, drink bottles. (T17: Ww *Explore* L2)

'I was quite surprised how interested the children were in this unit. Water is a very real and relevant topic to the children.'

> A great lesson. I thought the Volta sheet and timeline activity a bit boring but the children didn't mind and, in fact, still talk and remember information about Alessandro Volta. Worked really well. (T12: EC S3 Explore L2) [Indicates that 'Science as a Human Endeavour' content can attract students.]

At other times, teachers may believe that some conceptual understandings are beyond primary students. The research literature clearly indicates students can learn about physical and chemical change, but this was not the view of some preservice teachers:

> The student teachers that were also with me were fascinated that students were actually being allowed to learn about physical and chemical changes—something according to them had only occurred in secondary [school]. (T10G: CD S3)

At times, teachers' comments were in stark contrast as to whether the content was appropriate at the suggested level. In the *Smooth moves* unit, some teachers were surprised at what students could manage and the ideas they had:

> It has surprised me how the children *have taken a difficult concept and understood it*. (T1G: SM S2)
>
> I was surprised by children's initial knowledge. The children were *very involved and all were obviously enjoying themselves*. (T2G: SM italics added)
>
> I have found the module to be *interesting and thought-provoking* to me and the children. (T10G: SM italics added)

Other teachers (Ts 3, 4, 5, 6, 11) held contrasting views either over an entire sequence (*see* 'G' comments) or within particular phases. Apart from the following comments, *Smooth moves* teachers added that their students had difficulty with the concepts of gravity (T6, *Explore*), friction (T11, *Explore*) and 'force arrows' (T4: *Explain*).

> I think the whole of the *concepts involved here are too hard* for students beginning Year 3 and 4. I think they should just be experimenting with the forces and gaining experience and having fun, not expected to complete such closed and complex experiments, tables etc. which made it *boring and confusing*. (T3G: SM S2) [and later] ... Sorry I did not do this as requested. I just knew the students hadn't got the understandings or interest to do this as intended. I squeezed in extra lessons as best I could, but still couldn't come at this one. (T3: SM S2 *Explain*)
>
> To be honest, in my three years of trialling, this unit was my least favourite. It was *boring*—and for a year 5 class ranged from very easy/ basic/common sense to quite difficult concepts to understand. (T4G: SM S2)
>
> Many of my kids did not know about energy. This was a *very hard concept* for my kids to explain. The whole concept of energy transfer and where the energy went was difficult for some to grasp. We have been talking about 'forces' and now we are talking about 'energy transfer'. I will have to make this a teaching point earlier in our Lesson 3 and 4 discussion next time. (T10: SM S2 *Explain*)

It is of interest that despite the issues these six teachers raised about *Smooth moves*, some also referred to a range of positive experiences either overall (see 'G' comments) or in particular phases:

> I have found the module to be interesting and thought-provoking to me and the children. (10G: SM S2)[86]

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Note that T2 has said that SM S2 is 'boring and confusing' as well as 'interesting and thought-provoking'.

> The children loved these activities and particularly enjoyed the challenge of moving the ball bearing without touching it. These children did *Push-pull* previously so they were using terms such as push, pull and force regularly. (T6: *Explore*)

There may be other reasons why some teachers were struggling with aspects of the *Smooth moves* unit. One who expressed disappointment about this unit added later: 'This may be because I have no science background (except biology) but I really did try!' (T3G: SM S2); another added: 'You need to make physics fun' (T4: SM). The reference to 'physics' may reflect a negative predisposition towards this content area[87], and the former comment (T3) would be typical of many primary teachers (in that they either have no science or only a biological science background), especially in areas such as 'force' and 'movement'. If this inference is correct, then a teacher's predisposition towards particular Primary Connections' topics may discourage them from attempting the unit or they may see students' reactions through a 'biased' lens. What may be required here is to share comments from other teachers (and students) about how much they enjoyed the unit and what they learned from it.

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This is a speculative interpretation; there could be many other reasons, but teachers did vary markedly in their views about the SM unit as indicated in this section.

Relationship of content to students' everyday experiences

Teachers can differ in their perceptions of how a unit relates to everyday experiences. In the unit *Material matters*, one teacher commented that it did not 'relate' to everyday experience:

> Theme—The world around us—How does this unit relate to everyday experiences? Where does it fit content wise? (T10G: MMat)

Solids, liquids and gases is a topic that has been found to lack interest for students (Qualter, 1993), and another teacher did add: 'How can we make this sound fun?' (T10: SD S1). However, again, other teachers indicated how students in this unit 'related knowledge well from school to home' (T2G: SD S1) and how students 'made references to objects, even their lunches to solids, liquids and gases' (T11G: SD S1). Connections to everyday experiences were straightforward for these two teachers, and making such links may be one of the ways to counter Qualter's findings.

In contrast to the above two teachers, in the unit *What's it made of?*, a teacher asked why connect the study of materials and their properties to recycling:

> Why discuss recycling? Should be discussing properties (T7: ASS S2 *Explain*)

The implications of this teacher's beliefs (T7) may indicate that this property of a material could be overlooked; furthermore, teachers need to be making links between science and environmental and social matters (which are all associated with the meaning of scientific literacy).

Teachers' beliefs about complexity of concepts: contrasting positions

Another contrasting view about the complexity of concepts was in *Material matters* S1. One teacher introduced ideas that others may find problematical for younger learners:

> Used diagrams of molecules to explain states. (T1: MMat S1)

In the same unit, others felt the ideas were too complex:

> We are required to do a lot of explanation of highly complex and abstract ideas. (4G: MMat ES1)

'The student teachers that were also with me were fascinated that students were actually being allowed to learn about physical and chemical changes—something that according to them had only occurred in secondary school.'

In *Material matters* S1, this teacher (T4) is referring to ideas about solids, liquids and gases, about which several teachers reported positive comments. Clearly, different teachers have different perceptions about what is too complex for primary learners. Naturally, some concepts are beyond primary learners, but many that have been thought inaccessible, have been found to be within students' understanding with different pedagogical approaches (the particulate nature of matter is an example) (*see* Acher, Arca & Sanmarti, 2007). Primary teachers need to be open to the effects of different pedagogies, especially if teachers are reporting opposite experiences with similar concepts and related content. As stated earlier in this report, teachers' contexts vary so much that there could be many other reasons for the different responses to a Primary Connections unit.

Teachers' beliefs about complexity of activities

Depending upon a teacher's perception of their science background, or maybe other factors, they may be hesitant to try some Primary Connections activities. Some examples have been mentioned earlier in this report. This may be a false fear for some, as one teacher found:

> Children really enjoyed the water meter. I found this much easier than I initially feared. (T10G: Ww)

Encouragement and support may be all that is required.

11.14 Teacher beliefs about pedagogy in science

Several issues arose that suggested teachers hold a range of beliefs about what is appropriate pedagogy in primary science. In the following, obtaining a balance between hands-on and minds-on science created tension for some teachers, and was probably more apparent with teachers of younger learners. Two other areas are noted below: firstly, a teacher's trust in 'pedagogy' consistent with constructivist learning caused concern, and secondly, the question of the role of explicit teaching in science.

The above beliefs, at times, led to teachers either abandoning specific lessons or making (sometimes significant) adaptations to Primary Connections lessons. In reporting these contrary views it must be remembered, as emphasised in various places in this report, that other teachers of students in the same stage reported successful lessons; this reiterates that the many facets of the teaching context can account for why some teachers reported success while others expressed difficulties. This does not discount that teachers' beliefs about appropriate pedagogy for students can impact on what teachers do in classrooms.

Tension between hands-on activities and scaffolded direction (e.g., discussion, writing)

Many comments commended the hands-on activities within units: examples included:

> The best activity. Hands-on just great. (T6: PA S2 *Explore*)
>
> Brilliant lesson, children love hands-on, able to cater for full range of abilities. (T15: EC S3 *Explore*)
>
> This session was when the fun began. All groups were engaged and enjoying the hands-on. (T18: EC S3 *Explore*)

This is quite an appropriate response, provided teachers also appreciate that there needs to be discussion between peers and with the teacher about hands-on tasks (Skamp, 2007), and that quality science is not simply hands-on tasks (as has been appreciated for many years: 'activity by itself is not enough. It is the sense that is made of it that matters' [Driver, 1983, p. 48]). The following teachers expressed this well:

> Good mixture of discussion (sitting still) and moving (observing, walking, purposeful play, role-play)—better balance throughout unit and most importantly, within Lesson 4. (4G: OM S1) [Lesson 4 was an *Explore* lesson in the final version of this unit.]

This next extract, may refer to written or verbal reporting: commending the balance of units,

> There has been a good balance of activity and scientific reporting. (T13G: ASS S2)

The 5E model expects that key ideas and science inquiry skills will develop from students experiencing the learning sequence. Some teachers, such as the above, appreciated this requirement; it is also emphasised in:

> Teacher and students spent too much time playing with the toys, needed to spend more time looking at the 'science' within the activity! (T10: OTM *Explore* L4 [about 'Toys that move']).

In an *Elaborate* lesson called 'In a spin' [about helicopter flight], several teachers made related comments:

> Children wanted to play initially. Needed to revisit steps 12, 13, 14, 15 & 16. (T10: PP S1 L6 *Elab*)
>
> Session 1 is a nice progression .... Session 2—fantastic demonstration. Some really good comments by students. (T2: PP S1 *Elab* L6: this teacher positively commented on student talk across several phases in this unit)

On other occasions teachers expressed concern that directed scaffolding was required and not further hands-on activities, or simply that too much discussion was expected:

> I think the whole of the concepts involved here are too hard for students beginning Year 3 and 4. I think they should just be experimenting with the forces and gaining experience and having fun, not expected to complete such closed and complex experiments, tables etc., which made it boring and confusing. (T3G: SM S2) (and later) ... With classes of 31 there isn't the chance to observe each student or interact with/ question even each group adequately. They enjoyed trying out various ways to move

> the boxes, but found the talking about it boring. It seemed they thought it was all pretty obvious and not worthy of so much discussion. (T3: SM)
>
> The hands-on activity really got the students interested in the topic … BUT there was a lot of discussion and students tended to get bored and restless. (T11: SM)

It has been argued that teachers need to use different questioning styles in various parts of the 5E cycle (Hackling, Smith & Murcia, 2010), as well as different types of talk (discussion, dialogue and argumentation, as outlined in Chapter 8) in an inquiry-oriented classroom. While these teachers may have practised these approaches, they may also be resisting the need to alter forms of teacher-student interaction in order to engage young minds in talk that captures their attention (especially when it is appreciated that other classes had considerable success with the same lessons). As another teacher added:

> It has taken up quite a bit of our time because the concepts do need discussion and investigations not to be rushed. (T10: SM)

Although time is always an issue, students sometimes need to be able to 'mess around in science' (in an orderly way with materials) (Hawkins, 2002) in order to be able to contribute to more meaningful discussion. This approach is acknowledged in:

> We spent more than an hour rotating around different stations where we had magnet/ experiences set up. This was valuable and enjoyable. Some students were beginning to see past the activities to the properties of magnets and to suggest other things to try. *As a result of this long exploration time, they were quite happy to focus on the measurement task in the next lesson, but we only got to 8 in another session, because they discussed then wrote about what they knew about magnets before moving onto the measuring*. (T3: SM *Explore* L3 italics added)
>
> I felt it helpful to cover aspects of static electricity so the children could gain greater understanding of the exchange of 'electrons'… (and later) I did a bit of work via diagrams to help in their understanding about electrons. It is the electrons that move when an energy source is applied to a circuit …. (and later) *Much 'free play'/ experimentation time was given over the weeks as the children were given their own bag of equipment to keep*. (T17: EC S3 *Explain*, italics added)

'Messing about' *is* important, as is the opportunity to share thoughts about what is being 'messed about'. These teachers (Ts 3,17) appeared to reap the rewards of a freer messing about period in the *Explore* phase.

Even when the above is appreciated, some teachers may feel a constant tension between ensuring adequate time has been provided for scaffolding so that students have the opportunity to (re)construct their ideas about the phenomena they are observing and/or interacting with:

> Needed two sessions for session 2 for proper discussion, questions, making sure instructions are understood etc. (T4: SM *Explore* L3)

Teachers reacted to this need for focus in different ways:

> I elected to do session 2 as a demo with student 'helpers' and it worked just as well. I was able to ensure students focused on what was happening. (T8: DC S3 *Explore* L3)

This tension between action and doing can be seen with the following two teachers, both of whom helped their students 'reap the rewards' of 'thinking scientifically' rather than only 'working scientifically' (Feasey, 2012). This is not meant to imply that finding the balance can be a challenge (as T3 indicates):

> The lead up to the actual 'doing' of the experiment was too long for my class. They really went off track and I felt they needed to get stuck into the question making and experiment quicker .... Keeping kids on task in beginning of fizz wiz—*lots of discussion which was great,* but took us a while. (T3: CD S3 *Elab* italics added)
>
> The actual work on tablets and the variables was great, although *we spent a lot of time discussing it, lots of questions and answers, lots of 'What do you think...?' etc.* The ch[ildre]n (I think) are grasping how the differences in tablets size/shape/broken/exposed/hard etc. affect the way the tablets work and how well they work. (T9: CD S3 *Elab* italics added)

A related issue: students' writing in science

It is well documented that asking students to write too much in science can detract from their interest in the subject (Logan & Skamp, 2008), although when students are writing with a purpose, such as a means of sharing their results and not, for example, note taking, this generalisation may not apply. Teachers need to weigh up the benefits and the disadvantages of writing for meeting a range of learning outcomes:

> Journal was started in science books, students tend to be more motivated by hands-on approach, and writing observations and reflections is time consuming for disadvantaged kids. (T5G: EC)

Appropriate activities for younger learners

Some teachers of the youngest learners expressed some concerns similar to the above, but with the focus more on the age of the learners and what types of activity (and pedagogy) was appropriate for them. In the *Weather in my world* ES1 unit, many comments were made about the inappropriateness of some of the activities for students in their first year of school (Kinder, Prep), and sometimes Year 1. Typical remarks (Ts 1, 4, 5, 7, 10, 11, 12, 15) were that there was an expectation of too much discussion and there were not enough hands-on activities:

> Lots of fabulous activities but too long and sometimes too complex for the beginning of Year 1. (T5G: WW)
>
> Too much time sitting down. Had to adapt activities to move the (Kinder Term 1) children around. (T10G: WW)
>
> Lessons did not include enough 'hands on'. (T1G: WW)
>
> Be aware of the limitations of a young Prep group in concentration, listening, discussion, reading, group work. (T7G: WW)
>
> The ideas were good but better for children in Level 2, not Preps in Level 1. (T12: WW)

Learning science for younger students does need to find an appropriate balance between 'activity' and a focus on 'content' and conceptual learning. Several early childhood educators (Metz, 1998) argue that we have underestimated the reasoning abilities of younger learners and their desire to discuss how their world works. Some *Weather in my world* teachers (e.g., Ts 11, 19) did make adjustments to the lessons for younger learners to, in part, accommodate this need:

> Broke most of the sessions into 2 focused lessons of 40 mins with daily revisits of 5/10 mins to reinforce the topic. (T19: WW)

Further, at times, determining the appropriate level for a unit is not straightforward. One teacher commented that the *Weather in my world* unit was 'too easy for Year 3'. (T18: WW)

These beliefs of early Stage 1 teachers were sometimes reiterated for Stage 1 units.

In *Material matters*, some teachers indicated that less teacher direction was more appropriate at this stage:

> Most lessons were teacher directed rather than student led inquiry. (T5G: SD S1)
>
> [There needs to be] more time on activities, change groups more often, test more objects, less writing more drawing, how to test variables fairly. (T8G: SD S1)

Striking the balance is the challenge, for, as Harlen (2009) argued (Chapter 8), understanding involves 'talk' (interpreted from a broad perspective) for effective learning to occur.

Trust in constructivist underpinnings

In the *Engage* phase teachers are encouraged to help students reveal their ideas. This sometimes caused consternation for teachers:

> Recording student observations was very difficult, so we talked about what we saw instead. The class really went off track when we writing up what we thought we knew about 'Forces'. I fear the children will learn the incorrect thought as they are accepted and put on the wall. Upon reflection, I feel I should not put the very incorrect answers up. (T5: SM *Eng*)

Other teachers have also expressed this concern. Gibson (1992, p. 7), commenting on a 10 year old's non-scientific view about the movement of the Earth, proffered:

> The idea that children might go away believing the 'wrong answer' seems very prevalent among teachers, and causes anxiety. I think that the anxiety is misplaced. Accepting a child's ideas as positive contributions, and building on them, is more likely to lead the child to question her thinking, than giving her the answer which she cannot accept intellectually but must be right because the teacher says so.

The above teacher (T5) did not intimate that answers would be given; even so, Gibson's advice does suggest ways forward. Other suggestions could be ensuring students return to their views at a later time in a sequence and reflect upon them, and encouraging students to express their views so that more than one view is present in relation to a particular event or phenomenon, and, hence, needs resolving (also *see* suggestion in Harlen [2001]).

The role of explicit teaching in primary science

Feasey (2012, p.71) argues that 'science, like maths and language, requires a high level of teacher input to ensure student success' (also *see* Fleer, 1995). Teachers accept that this is required for language and literacy development, and that it takes time:

> Suggested time for sessions way out, especially if explicit teaching is to occur with literature component. (T7G: PA S2)

As Primary Connections combines explicit teaching (at appropriate times) with exploration and application of ideas through hands-on and minds-on tasks, then teachers must appreciate that time be included in their planning for explicit teaching in science (where appropriate). This is more critical when students are not familiar with various science specific literacies, as indicated in the following:

> My first go at this (*Explore*) lesson was a mess ... .Children had no previous experience of science. There was some pre-teaching needed for my slow learners. I needed more than double the time .... I had to do several lessons on the structure of the procedural text before using it with the experiments. (T5: PA S2 *Explore*)

There is also a need for whole class teaching at times (e.g., *see* Bybee, 2002 and teachers' roles in section 6.93), in order to bring the conceptual 'threads' of a lesson and/or sequence together.

Resistance to outdoor learning

Some teachers are known to be hesitant about learning in the outdoors (e.g., *see* Skamp, 2009). How this perception can influence proposed teaching and learning strategies is shown in the following:

> Overall, the content is excellent but the application is not very realistic. Very difficult to do real searches with the kids. I would prefer to arrange a trip to Botanic Garden or National Park to have rangers and parents help search for and collect data on animals than stick to internet, books and DVD resources at school. (3G: Sz S1)

Sometimes there may be other reasons:

> I stayed within the classroom where there was a greater variety of materials, children were more familiar with area, were able to recognise features more easily on a map, and no weather restraints—temperature up to 40°C. (T5: WM ES1)

In contrast to these teachers, most teachers' comments strongly supported these outdoor activities in *Schoolyard zoo*, and in other units teachers found it a motivating approach:

> They liked how we did science outside the classroom (when melting the ice blocks) and that it was a fun way to learn. (9G: CD S3)

11.2 Teacher confidence to teach primary science

Teachers' confidence to teach science appears to have been influenced by a range of factors related to Primary Connections. These included, firstly, *teaching* the Primary Connections units (cf. section 2.54), and secondly, the subsequent *enjoyment* that teachers experienced. This enjoyment was usually a consequence of observing the impact Primary Connections had on their students' interest in science and their learning. Access to readily available *science background* material, as in Primary Connections, also appeared to assist confidence, as did the Primary Connections professional development 'activities'. Sometimes, a few teachers expressed negative feelings about a particular unit; when these feelings were not balanced by more positive feelings in other sections in the unit (which they usually were), then the impact on these teachers' confidence became problematic.

11.21
Teaching Primary Connections: a positive impact on confidence

Although beliefs about teaching approaches can be difficult to change (*see* section 2.63), teaching using the Primary Connections framework may change teachers' confidence and the way they think about teaching science:

> This unit (*On the move*) was easier/less open/more directed ?! than Term 1 with [*Weather in my world*] I think the new weather ideas we worked on in … will make that unit easier to follow. But, *it may be that I am getting more comfortable with the whole idea of teaching science this way*. (8G: OTM S1, italics added)

Such changes may even occur for teachers who have a resistance to teaching science because they believe their science background is inadequate:

> Team teaching is difficult when the teacher you are working with has no science background. I think she is now a convert and sent me an email thanking me, so something must have worked. (T1: OM S1 *Eng*)

11.22
Teacher enjoyment in implementing Primary Connections

When teachers enjoy teaching science, then this may increase their 'science teaching self-efficacy', which is a combination of their perceived ability to teach the subject and their belief of being able to impact on students' science outcomes (e.g., *see* Enochs & Riggs, 1990). For some teachers science seemed more attractive to teach, as with this Early Stage 1 teacher (underlining indicates 'enjoyment'):

> We are particularly impressed with the most recent science units for Early Stage 1 and Stage 3. They have been a dream to teach and share the learning experiences with our classes. (T3G: OTM ES1)

For other teachers, Primary Connections impacted on teacher enjoyment when they observed student interest and improved student outcomes. Feeling more 'comfortable' with teaching science as a consequence of the Primary Connections approach is especially apparent in the following. This teacher (T9) expresses how seeing the effects of their teaching on student learning can influence their own enjoyment of teaching science (italics indicates impact on students):

> The discussions around why we categorise were amongst our best of the unit. Whether it has taken this long to assimilate the information or *the fact I was more comfortable* seems to have had a bearing on this last component. (T9: CD S3 *Explore* L5) …. All the students talked about having taken 'fizzy medicines', and so this experience was common to all. Fitting together the reasons why tablets fizz and the fact they actually are doing a job *was like watching light bulbs go off. It was very rewarding for me!* (T9: CD S3 *Elab*)

Other teachers of the same unit (CD) expressed similar feelings:

> This unit was brilliant—and most of the activities were VERY motivating. What was terrific though was that all the equipment was readily available (most of which we already had) and the experiments were simple—yet very effective. This is one of the most enjoyable senior units I've come across—both from the teaching and *learning point of view*. It was worth the wait!! (T8G: CD S3)

These types of responses were found across most units. The following indicate different 'types of (positive) impact (of Primary Connections)' on teacher enjoyment in teaching science.

'We are particularly impressed with the most recent science units for Early Stage 1 and Stage 3. They have been a dream to teach and share the learning experiences with our classes.'

The impact on student learning (investigating scientifically)

> I have *really enjoyed teaching* this unit. The best aspect of this unit was that it provided hands-on activities for the students to engage with *in a meaningful* way, *finding out answers by testing possibilities themselves* provided *a real sense of ownership of their learning*. (T22G: ASS S2 italics added)

The impact on student interest in science and student learning

> I found the topic easier to teach because I personally was more motivated. I *enjoyed teaching* a topic for the first time and *observing high level of student interest* .... Word usage of *scientific language was increased* and improved upon. (T2G: MM S3)
>
> *The unit was great fun* and, I believe, *met the outcomes* stated in the unit. I found the possibilities unlimited to extend this unit in all directions. (T18G: EC S3)
>
> We have thoroughly enjoyed teaching the science units, as the *children we teach have wanted to do nothing else but science*. (T3G: OTM ES1)

Other reasons why teachers enjoyed teaching Primary Connections

Apart from the above, there was a range of reasons why teachers may have enjoyed teaching Primary Connections units (and probably leading to increased confidence)—reasons are in italics:

> Thanks for the chance to do this. I found it stimulating and very easy to use. *Lessons were a good length and fit in well to a term's time span*. (15G: EC S3)
>
> This has been an excellent unit of work *with clear goals and observable outcomes*. (9G: CD S3)
>
> I especially like the *unit overview* and *'Lesson at a glance'*, as they enable me to quickly revise what we were going to do. (T1G: OTM)
>
> I like the *layout of the unit*—Lesson at a glance, Background information, & Equipment lists at beginning of lesson. Each lesson step is clearly set out, easy-to-read. (T4G: OTM ES1)

Some trial units influenced teachers in contrasting ways, for example, *All sorts of stuff* S2:

> Students and teachers *thoroughly enjoyed this unit* and we all *learnt heaps*. (T6G: ASS S2)
>
> I found this unit *very hard to be enthused about*. (T8G: ASS S2)

The same was true of a few other units, as indicated in various places in this report. As has been stressed elsewhere, all units impacted positively on some teachers, with the vast majority of units having a positive impact on most teachers. There were, however, a few units, in which a small minority of teachers expressed negative views. The following teacher's comment was the most negative among the 16 units; other teachers, at times, did express difficulties about various units, but not as in:

> **'Fitting together the reasons why tablets fizz and the fact they actually are doing a job *was like watching light bulbs go off. It was very rewarding for me!*'**

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In section 7.7 a further comment is made about this reaction to SM. Of interest is that T4 (SM) had taught previous Primary Connections units, and hence this was a comparative comment. Earlier experiences, by implication, had been positive.

> To be honest, in my three years of trialling, this unit was *my least favourite*. It was *boring*—and for a year 5 class ranged from *very easy/basic/common sense to quite difficult concepts to understand*. Did *not enjoy this unit*. You need to make physics *fun*. (T4G: SM S2)[88]

11.23 Primary Connections professional-development 'activities': impact on enjoyment

In developing confidence in using new pedagogy or introducing new content, some teachers drew on their professional development experiences (cf. Fittell, 2010a,b):

> *Teachers loved this activity at workshops*. (T13: ASS S2: the activity was 'Snap, Tear or Stretch', related to properties of materials.)

This is a fairly common phenomenon, in that teachers' enjoyment of teaching an activity (and probably confidence to teach) is enhanced if they have tried it successfully in professional development (or preservice) situations. Such a confidence may not be enduring until such teachers feel the same way about 'new' activities they have taught.

11.24 'Science background' in Primary Connections' influence on confidence

Many writers have argued that primary teachers' limited science background erodes their confidence to teach science (e.g., Holroyd & Harlen, 1996). Teachers who most encourage inquiry-oriented science are often those with 'intermediate' science knowledge background, not necessarily those with a strong science background (Dobey & Schafer 1984). Primary Connections provides succinct descriptions and explanations of key science ideas related to common alternative conceptions that students and teachers may hold. Teachers reported that it had assisted their confidence to teach science. Some examples follow:

Change detectives

Typical of positive comments (Ts 1,3,5,6,7,8,9,10) about the value of the 'Background information' for the S3 unit *Change detectives* was the following (T6). Some indicated that it was more 'than I have thought about' (T9), but even early childhood teachers benefit from a deeper 'basic' knowledge about the concepts that are the focus of students' learning (Schibeci & Hickey, 2000); also *see* T7: OTM ES1 below. Another teacher still sought assistance about how to translate the 'background information' for students (T7), although this was not a pedagogical content concern for most teachers of this unit:

> Very clear information, although I had to reread the material so my explanations, knowledge and confidence was maintained. (T6G: CD S3)
>
> I felt far more comfortable with this unit of work (although taking 'a while to feel comfortable with my understanding of the terminology'). (T9G: CD S3)

> I find this information extremely useful—it helps me to focus on the topic and helps me to answer questions from students when they arise. (T20G: ASS S2)

Spot the difference

In *Spot the difference* (S1), some teachers (Ts 2,8,13) commended the value of the science background about solids, liquids and gases: It 'is *very* important' (T2: SD S1, emphasis in original), while at least one thought it was 'too wordy' (T3: SD S1) for Years 1 and 2[89].

'We have thoroughly enjoyed teaching the science units, as the *children we teach have wanted to do nothing else but science.*'

Electric circuits

Eight teachers complemented the value of the 'science background' including, it 'was very helpful (especially since science is not really my forte!)' (T3G: EC). By way of contrast, there are primary teachers with a sound science background; one suggested that some information be added about 'how 'mains supplies' works' as otherwise students may have an inappropriate conceptions about this aspect (T19G: EC).

On the move ES1

The background information was appreciated by early childhood teachers as well: 'Excellent—gave me lots of info to sound 'clever' with'. (T7: OTM ES1 L4)

Schoolyard zoo ES1

As with other aspects of Primary Connections, at times, the contrast between teachers can be stark:

> Teacher information was too long and detailed, I think most teachers would just skim read or not bother. This is a lot of technical information, not really a good focus for Stage 1. Can put teachers off before they start. (T3G: SZ S1)
>
> I thought was a very good unit. I really like the set out and, once again, the teacher background information was a major bonus. (T14: SZ S1)

11.3 Cross-curriculum links with Primary Connections

Teachers, in general, made numerous comments that either stated or implied support for the relationships that Primary Connections provided for addressing literacy outcomes while students were also learning science, for example: 'Science and literacy "married" better, and literacy matched what I would have been doing anyway' (T3G: OTM ES1); 'Literacy focuses were a good way to integrate unit and also allowed you to ensure that students had background knowledge before lesson' (T14G: SM S2). Teachers of reform-focused primary science saw science as being linked to everyday life and, hence, it was only natural that it had horizontal links across the curriculum (Ref Tempered teachers). Whether these Primary Connections teachers perceived the science-literacy links in that light is not known; however, they did see the benefits in the literacy links, as well as to other curriculum areas (cf. Feasey, 2012). This would seem to be an enabling

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It was unclear as to whether the teacher (T3) felt it was too long for the teacher to read or whether they were going to use it with their students. If the latter, it could be an inappropriate use of Background Information.

factor for increasing the quantity and quality of science at the primary level. One teacher, though, needed to 'take-on-board' science taught in this way—it was a new approach:

> I didn't really do it justice. Time was a factor. Each lesson took forever. Being new to this whole Science-can-go-into-all-subject-areas thing. (10G: PA S2)

11.31
The realised potential of science literacy connections for literacy learning

Many examples were cited by teachers of the wide range of learning opportunities provided for literacy learning. In the *Marvellous micro-organisms* unit, the lesson focusing on Van Leeuwenhoek, which students in general found 'interesting' and 'motivating' (T2G), led to the following:

> ... summarising (T4) ... a note taking and summarising activity to share and discuss (T5) (leading to a poster production) (T16) ... a comprehension activity (Ts 8, 17, 18) (use in) reading groups (Ts 10, 21) ... (a great) language lesson (T14) ... Jot thoughts—Used colourful sticky notes to record ideas and displayed posters in class (16).

Similar comments supporting the literacy activities were forthcoming when Galileo was the focus in *Spinning in space* (e.g., T2 SS S2 L4) and Volta in *Electric currents* (e.g., Ts 12,13). Teachers appeared to readily link literacy with science when there were resource sheets provided, as in these two historical examples. It also occurred in many other science activities (e.g., *see* Chapter 8).

These literacy outcomes were also occasionally addressed with other languages; for example, 'throughout the [*Staying alive*] unit LOTE will be taught as a curriculum link with vocab being taught and worked on'. (T5: SA ES1 L4)

Although there was strong support for these opportunities, some teachers did indicate that some literacy skills needed further attention before the science/literacy outcomes could be advanced: 'Need 3–4 sessions plus explicit teaching how to write a summary. It was difficult. ... This was quite difficult as children had never written a summary before—many wrote a recount type of text' (T12: PA S1 *Explain*); 'None of my students had ever heard of a summary'. (T13: PA S1 *Explain*)

11.32
Integrating science in Primary Connections across the curriculum: positive teacher reactions

The ease with which Primary Connections enabled science to link with other subject areas and assist in addressing the learning outcomes of other subjects was perceived positively by many teachers. In the unit *Water works* (*see* italics):

> *We found the concepts in this unit to be very easy. The children had a vast knowledge of water concepts.* The literacy aspects were very strong and covered a broad range of genres. Links to other areas were easy to make. *The unit is well set out and flows appropriately. The children enjoyed the hands on activities and using computer technology.* (T4G: Ww S1)
>
> This is a great unit suitable for all students, Year 1, 2 and few 3s (7). Teachers were apprehensive about having 2 hour RFF science sessions but *were won over when explained to them the other areas covered (English, Maths, Creative Arts).* (T7G: Ww S1)

> *Very easy to work other KLAs into this unit.* (T8G: Ww S1)
>
> This was a fabulous unit—the *children* really enjoyed it and learnt a lot. *It was really easy to integrate right through the curriculum.* (12G: Ww S1 emphasis in the original)

Similarly, in *All sorts of stuff* and *Change detectives*:

> This lesson opened up a lot of opportunities for extra activities in English and SOSE. (T14: ASS S2 *Explain*)
>
> Used drama and learning objects in conjunction with questions. (T5: CD S3 *Eng*)
>
> I think they liked a different approach—it was science but we doing drama! (T9: CD S3 *Explore* L2)

Although these *Water works* and other teachers strongly supported the value of Primary Connections in this regard, the caution by Venville, Wallace, Rennie and Malone (1992) is noted, that is, the integrity of a subject, in some circumstances, may be eroded through integration. This, however, does not appear to be the case with these units.

> **'This was a fabulous unit—the *children* really enjoyed it and learnt a lot. *It was really easy to integrate right through the curriculum.*'**

11.33
Integrating science across the curriculum: varied teacher reactions

Occasionally, there were varied reactions to the suggested literacy links, but they were rare. In PA, for example, two teachers strongly complimented the links, while another (T8) felt there were not enough: 'The literacy aspects were excellent. Relevant to activities right across the curriculum. Science became the lynch pin of teaching program' (T2G: PA S2); 'Literacy focuses were a good way to integrate unit and also allowed you to ensure that students had background knowledge before lesson.' (T14G: SM S2)

> The *Plants in action* lessons 'need to be integrated with thematic units' said one teacher. (T8G: PA S2)

11.4 Primary Connections reform agenda and meeting system requirements

Primary Connections aims to contribute to students' scientific literacy. Its goal is to establish science within the primary school curriculum through an inquiry-oriented pedagogy that requires sequenced teaching, so that students can develop better understandings about how science and our world work. Although science is mandatory in Australian schools, the Primary Connections' curriculum and pedagogical agenda represents a 'reform' package for many schools and teachers. Earlier sections in this chapter have indicated the impact Primary Connections has had on some teachers' views about science pedagogy. In this section, teachers' comments that referred to system requirements are

'The literacy aspects were excellent. Relevant to activities right across the curriculum. Science became the lynch pin of teaching program.'

considered, as they can influence whether reform agendas are successful or not (*see*, e.g., sections 2.55 and 2.56). Most teachers' comments indicated that system and school requirements could still be met while implementing Primary Connections.

11.41
Primary Connections facilitates its own reform agenda

Primary Connections can have a significant impact on individual schools:

> This unit has raised the profile of science in the school. (T5G: SD S1)

In several instances teachers indicated how Primary Connections could be integrated into existing system requirements in general:

> It [Primary Connections] still allowed for integration of science unit into school context. (T2G: SD S1)

In NSW, a teacher indicated how it blended into a Department of Education initiative (NSW DET, 2008)[90] 'Connected Outcomes Groups':

> We used our observation of ants and their trails along with research to write 'information reports'. Also studied life cycle of ant as part of COGS unit studied this term. An assessment task was to draw an ant on the computer on *Kidspix* and label. The children thoroughly enjoyed this and have gone on to do it with snails. (T7: SZ S1 L4)

In Queensland:

> The Ants topic fitted in perfectly with Year 2 validation task done in term 2 in Queensland. Children have to write a report on an ant colony, roles of ants etc. and read L12 Pm benchmark book on ants, so word wall and exploration fitted in really well. (T2G: SZ S1)

Some teachers' concerns about addressing the requirements of other curriculum areas were addressed because of the Primary Connections science-literacy (and other subject) links:

> This is a great unit suitable for all students Year 1, 2 and few 3s .... Teachers were apprehensive about having 2 hour RFF science sessions but *were won over when explained to them the other areas covered (English, Maths, Creative Arts).* (T7G: Ww S1 italics added)
>
> Science and literacy 'married' better, and literacy matched what I would have been doing anyway. (T3G: OTM ES1)

Teachers, at times, made suggestions that would assist Primary Connections to meet system requirements:

> An idea would be to have factual recount or text type that is linked with unit included in literacy focuses at the front of the book. This will allow school scope and sequences to fit science and literacy closer together. (T16G: EC S3)

It is worth noting that Primary Connections does provide teachers with information about how its units are consistent with system requirements.

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See for example: Curriculum planning, programming, assessing and reporting to parents K-12: http://www.curriculumsupport.education.nsw.gov.au/timetoteach/cogs/curricplanframe.htm (Retrieved March 22, 2012).

11.42
Primary Connections adds stress to meeting system requirements

Some teachers did not hold the above views, as in:

> I really wanted to complete all the activities because they were so well thought out and sequenced. This came at great cost to the class program in other KLAs. For instance, we are now 10 lessons behind where we were in Maths at this time last year. Our HSIE unit was basically non-existent. For this unit to succeed in normal classrooms it needs to be carefully pruned down to essentials. (2G: PP S1)
>
> I find the shift to liquids, solids and gases a little off track for the NSW syllabus and also disjointed …. I don't know that I would teach it again, especially as a lot of it doesn't really fit under the NSW syllabus. (T7G: SD S1) [It may be noted that 'liquids, solids and gases' is not inconsistent with the NSW Science and Technology (K-6) syllabus.]
>
> HSIE: Already have a HSIE unit which I've had trouble trying to 'fit in' my week. If my HSIE unit hadn't been pre-ordained, I would have done a Toy unit. (T4: OTM ES1 L4)

Unlike the above examples (section 11.51), this teacher (T4) may not have seen the integration possibilities.

11.5 Potential barriers to the implementation of Primary Connections

Many barriers to the implementation of reform agendas in science education at the primary school level have been documented (e.g., *see* section 2.5). Several were identified in these teachers' comments.

11.51
Lack of familiarity with research evidence about student learning

Teachers, at times, expressed frustration with what they perceived to be the Primary Connections' expectations of student learning. This occurred for science understandings and science inquiry skills.

Science understandings

In the following are some examples with associated commentary related to research findings.

> Observation of candle and my best efforts at questioning were not enough to convince half of the class that candle burns wax. They still believe wax melts and even evaporates and the wick burns and half of them can't get past this. When asked can you get the wax back they say 'yes, by condensation'. We have weighed candles, compared 4 and 9 hour tea candles and collected soot, but for half of us, to no avail. I've taught them all I know and they still don't know anything! (T5: CD S3 L4 *Explain*)

Here, this teacher has shown considerable initiative in encouraging her students to collect and then think about varied forms of evidence. There is little more that could have been done at this level. If this teacher had appreciated the difficulties some primary students have with chemical change (not to mention secondary students and adults) (*see*, e.g., Skamp, 2012c[91]), then there may have been less frustration, and an acceptance that not all students will modify their ideas about such a 'big idea' (*see* section 6.8) over a short period.

Answering the following question also would be assisted by teachers appreciating students' intuitive understanding of what constitutes matter and, hence, listening to what students think about what they are observing (here, their tests of properties of materials) to explore how far a teacher can scaffold possible 'explanations' at different primary levels:

> How does one explain tensile strength with children? What level of understanding is needed in Year 4/5? (T19: ASS S2 *Explore*)

Primary Connections does provide concise summaries of students' existing conceptions related to various levels. Sometimes teachers may need access to further research findings. Primary Connections cannot meet this need and teachers cannot be expected to be familiar with the findings of numerous studies. A knowledge of the broad outcomes of how students learn science from a constructivist perspective may assist.

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When students do not appreciate the particulate nature of matter, then understanding chemical change makes little sense to them. Most primary students do not have an understanding of the particulate nature of matter. This does not mean that chemical change be omitted from the primary science curriculum; rather, stepping stone understandings can be laid, while accepting some students' ideas will not change (Skamp, 2012b, c).

11.52
Perceived lack of consideration of pre-requisite skills and knowledge

Sometimes teachers referred to the time taken for students to learn prerequisite skills and processes in order to implement aspects of Primary Connections:

Co-operative groups

> Co-operative groups could be difficult if not used to working this way, takes a long time to establish, it could be a complex step with a couple of lessons to get them started, can't just pop them into a lesson. (T10: SD S1 *Eng*)

With practice, some teachers reported that such groups worked well:

> Group work happening well now automatically assigning and carrying out tasks, working constantly with different peers. (T22: MM S3)
>
> Students now familiar with group work, use 4 to a group adding scribe/timekeeper. (T23: MM S3)

PC FINDINGS

Virtually all teachers who commented on the literacy aspects of Primary Connections commended their inclusion

Science Inquiry Skills

In general, teachers commended the inquiry processes used in the various units and the opportunities they provided for students to develop SIS (*see* e.g., Chapter 8).

An exception was where the implementation of an inquiry process was hindered by a range of factors, as in the *Elaborate* phase of the *Smooth moves* S2 unit (this was discussed in section 7.7).

11.53
Teachers' limited use of scientific and pedagogical terminology

Of interest in analysing teacher feedback is the terminology that is absent from most or all of their remarks. This was most evident with pedagogical terms such as 'inquiry' (mentioned by one teacher on one occasion) and 'inquiry-based learning', which are pivotal to describing the approach to teaching and learning taken in Primary Connections and highlighted in the prefacing pages of units (e.g., AAS, 2008b, p.vii). Similarly, there was no reference to 'constructivism' as a theory of learning underpinning the 5E model, and it was rare to find teachers mentioning associated personal and social constructivist language, such as 'misconceptions' or 'dialogue'. With reference to assessment, only one teacher used 'diagnostic assessment' as a descriptor of what was happening in the *Engage* phase, and 'formative assessment' was not mentioned (*see* Chapter 9).

In relation to scientific terminology relevant to the above pedagogy, there were very rare references to the concept of 'evidence' (e.g., *see* sections 5.32, 6.5 and 6.6), a critical component of scientific literacy towards which the learning outcomes of Primary Connections contribute (AAS, 2008b, p.v). On another level, although still not common, more teachers did refer to the conceptual language of science ideas as they provided feedback, such as in:

> Ideal for revision of *solid, liquid and gases by developing an understanding that each substance needs to be held in an appropriate container*, introduced hazardous materials. (T21: ASS S2 italics added)

With reference to SIS (a term not used in Primary Connections until the advent of the new Australian Curriculum: Science in 2011 [ACARA]), teachers did mention skills such as observing and predicting, but rarely hypothesising or interpreting data. 'Representations' was mentioned on a few occasions, but not 'multi-modal' representations (AAS, 2008b, p.vii).

Whether the absence of this language in teachers' pedagogical discourse has any influence in what occurs in classrooms is problematic. These teachers are not unusual; other studies have reported similar findings (e.g., Levitt, 2001). A likely outcome is that, in some instances, a lack of familiarity with key conceptual language related to pedagogy (or the science that is being taught) could limit the scope of what a teacher implements in their classroom. The concept of 'evidence' illustrates this conjecture in this research study (*see* earlier sections).

11.54
Ease of access to equipment and materials

Although for some units, and lessons within units, teachers thought that access to equipment and materials was not an impediment to implementing the Primary Connections units, this was a regularly mentioned concern for many teachers. Interestingly, these concerns were sometimes balanced by very positive comments by the same teachers about the unit. Some examples of both perspectives follow:

Strand: Natural and processed materials

In the *Change detectives* unit, most teachers did not refer to difficulties with this unit, except for some safety concerns (Ts 1,3,5,6,9), which most teachers handled (e.g., T1 *Explore*). Also, the extent to which equipment was a barrier to implementation is problematic when, for example, in the *Explore* phase (L3), seven teachers commented about equipment issues, but all were pleased with the lesson. Even so, there were still stark contrasts:

> What was terrific though was that all the equipment was readily available (most of which we already had). (T8G: CD S3)
>
> A huge effort to set up and manage—not sure I'd be keen to take it on again. Could pretty much guarantee that other teachers would not have done it if the materials hadn't been set up for them. (T5: CD S3 *Eng*)

Only one teacher in the *All sorts of stuff* unit clearly expressed equipment and materials to be a concern, but also thoroughly enjoyed the unit: 'Huge amount of preparation, ordering and storage of materials became an issue' [but] 'Students and teachers thoroughly enjoyed this unit and we all learnt heaps'. (T6G)

Strand: Energy and change

In the *Electric circuits* S3 unit, teachers (Ts 2,8,18) commended the advice provided for organising the equipment; difficulties appeared minimal, although there were hassles with making connections in circuits (Ts 2,3,6,12).

Strand: Life and living

Sometimes it will be unavoidable that equipment issues will take time and cause difficulties. Teachers need to weigh up the benefits for the students. An example would be *Schoolyard zoo*, in which students had to keep invertebrates in the classroom (or nearby):

> From a teacher's point of view it was very time consuming to gather all the habitats for each animal. I also found the lessons were too long and needed to be broken up into smaller section. (11G: SZ S1)

Other teachers referred to birds eating the invertebrates' food (T1), ants escaping (T2), difficulty in finding particular invertebrates (T9) and animals not behaving as expected (e.g., not eating food) (T4). Despite these difficulties, many teachers reported how much they and the students enjoyed the unit (e.g., Ts 1, 2, 7, 9, 11, 13, 14, 15).

11.55
Need for aides or other helpers

Preparation for *Marvellous micro-organisms* was considerable, although again, many teachers highly commended the unit (Ts 2, 3, 5, 8, 9, 10, 12, 19, 23, 24, 25). One teacher said:

> BE PREPARED—buy utensils. Prepared all the ingredients to be measured, took this option knowing that lack of maturity in students could result in inaccurate measurements, took 40 minutes before school .... Who has blower heaters nowadays. Hit a foggy day so had to wait three hours before checking. (T13)

Two others indicated it was only possible with help:

> This was extremely worthwhile but took a lot of time to set up. Without Education Assistants we would have spent a lot of time setting up. (T16: MM S3)
>
> Definitely need aide or parent help to get each group set up. (T20: MM S3)

11.56
Inadequate time

This factor was a common concern for many teachers across all units. Despite this issue, teachers usually, but not always, added, in other comments, about how positive they felt the unit (or parts of it). Some examples follow:

Strand: Natural and processed materials

In *Change detectives S3*, several teachers (e.g., Ts 7, 8, 9) mentioned a lack of time. The complexity of this issue as a barrier is shown by the following teacher who said: 'This is one of the most enjoyable senior units I've come across—both from a teaching and learning point of view—it was well worth the wait' (T8), while adding:

> However, it was EXTREMELY heavy going in terms of time. Many of the 'lessons' required more than one session to complete and I found it hard with all the other commitments on top to do all the sections of each activity full justice. (T8G)

This teacher had to substitute vicarious for first-hand experiences as a consequence:

> I would have liked to have used the actual items, but timing (and available time) meant I had to use the photos mostly. This didn't seem to worry the students though. (T8 *Eng*)

In the *All sorts of stuff* unit teachers (Ts 2, 4, 6, 12, 20) also referred to inadequate time to complete the activities. The following teacher captures the tension between facilitating student learning and finding adequate time:

> So much in each lesson to complete in given time, especially as unit progressed, unit felt rushed and needed lots of extra time to complete all lessons.

This teacher (T6) added though:

> Students were highly motivated and enthusiastic, eager to experiment, predict, test and discover. ... All lessons had great hands-on activities, fun, challenging and stimulating. Many opportunities for integration across curriculum. Students and teachers thoroughly enjoyed this unit and we all learnt heaps. (T6: ASS)

Strand: Energy and change

Reports can vary considerably at times. In the *Electric circuits* S3 unit, one lesson (*Explore* L2) was 'a very short lesson' (T14: EC) for one teacher and 'took two hours but students needed additional time for timelines' (T3: EC) and was a 'L-O-N-G lesson' (T9: EC) for another.

The *Push-pull* unit caused difficulties for several teachers in the *Engage* (Ts 1, 2, 3, 4, 5, 10, 11, 17) and *Explore* (Ts 1, 2, 3, 10) lessons, and this may be linked to fewer and fewer teachers commenting on the later lessons (three for L8): for one teacher the class program was 'disadvantaged'. (T2: PP)

Strand: Life and living

Although the following teacher expressed concerns about time, both literacy and science time was used, which, in part, is what expected:

'Students were highly motivated and enthusiastic, eager to experiment, predict, test and discover. ... All lessons had great hands-on activities, fun, challenging and stimulating.'

> I found this unit extremely long. Many of what you set out as lessons took me 2–3 or more lessons to complete. I found myself using Science and Literacy time to get through it all (which is OK) and still running out of time to fit everything in …. (1G: SA ES1)

In section 4.6, the average time for completing a Primary Connections unit was about 7 to 10 hours. This was considered a reasonable time if one unit is taught across a term. Where teachers have expressed concerns about time, this may be because of expectations that other curriculum areas' outcomes need to be addressed (despite the comments in section 11.4), as well as the other multiple matters that have to be fitted into a school week. However, to reduce the time for teaching science may overlook the fact that to achieve science learning outcomes in an effective manner means having time for not just hands-on tasks, but also for student 'talk' in its various forms (as discussed in various sections of this report, e.g., 11.24 and Chapter 8).

11.57
Management issues

In general, there were relatively few comments about difficulties caused by management issues. Most Primary Connections teachers have considerable teaching experience and this may account for this observation. Different approaches to management may help overcome issues that some teachers confronted. This was usually recognised by teachers, as in:

> Need lots of scaffolding for observing. Children had so much happening some switched off, will need to remember this for future. Children will need lots of help with recording. They are really still Year 2 and *very* slow at writing and drawing. (T1: SM S2 *Eng*)

Although this was an issue that these teachers could overcome, there may still be value in introducing the concept of pervasive management in science (Harris & Rooks, 2011; also *see* section 2.21).

11.6 Implications for the implementation of Primary Connections: other factors

A summary of the findings and insights from considering these other factors is in Chapter 12 (section 12.8). Recommendations for improving future implementation of Primary Connections units, based on these findings, are listed. Each finding, insight and recommendation is cross-referenced back to sections in this chapter.

Chapter 12

Teacher feedback from implementation of Primary Connections: conclusions and recommendations

Introduction

Extensive and detailed written feedback from 206 teachers[92] who implemented 16 of the Primary Connections trial units has provided a rich source of data about teachers' thoughts of the strengths and weaknesses of the units. A content analysis of this data was completed, which identified whether teachers' comments indicated the presence of a range of 'actions' or 'events' that could be implied to have occurred in these teachers' classes. Teachers' perceptions about these actions and events were also identified. In summary, the data were searched for actions and events, as well as teacher perceptions related to them, that indicated whether:

- the 5E model was being implemented, as well as perceptions of its impact on teaching and learning (Chapter 4);
- the purposes of each of the 5E phases were addressed (Chapter 5);
- various learner roles associated with teaching science from a constructivist, inquiry and language perspectives (Harlen, 2009) were present (chapters 6 to 8);

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As some teachers may have responded to more than one unit, the actual number of teachers will be less than 206. However, the responses were, in effect, from 206 teachers, albeit sometimes the same teacher. The identity of the teachers who taught more than one unit is not known, unless they mentioned it.

- opportunities provided for the effective learning of primary science were present (as identified in the components of the SiS research [Tytler, 2003]) (chapters 9 and 10); and
- other issues that had facilitated or impacted on the implementation of Primary Connections units emerged (Chapter 11).

Chapters 4 to 11 in this report provide detailed findings and commentary related to each of the above areas. They will not be reiterated here. Rather, broad conclusions from each chapter will be stated and references made to the relevant sections, where appropriate. Recommendations that flow from the conclusions are outlined.

The inferential findings and insights drawn from this data have limitations. These need to be borne in mind when considering the conclusions. All the data are teachers' perceptions and self-reports of what happened. They are, therefore, impacted by the existing perspectives that each teacher brings to the teaching and learning context. Perhaps even more importantly, these teachers' comments do suggest what did occur or what views teachers may hold; however, as they were not asked to comment on the various attributes that were used to interrogate the content of their responses (e.g., particular learner roles), then the inferences drawn about the frequency with which various attributes were present must be speculative. This is because the absence of a comment about an action or event does not mean that such actions or events are not present in a teacher's class. This does not detract from the value of drawing various inferences; rather it provides pointers for further investigation and reflection by those involved in the development and implementation of Primary Connections resources, and those offering professional learning workshops.

12.1 Research questions

This project was guided by the following research questions (RQs):

General

The broad aims of this research are encapsulated in the following general research questions:

- What understandings and insights about learning and teaching of science are embedded in teacher feedback about the implementation of trial units of Primary Connections?
- What are the implications for the development of curriculum support materials from these insights?
- What are the implications for the future professional development of Primary Connections teachers from these insights?

Specific

In what ways does teacher feedback about the implementation of trial Primary Connections units imply:

i) teachers' understanding, and practice, of the 5E learning cycle and associated constructivist and inquiry-oriented pedagogies (e.g., purposes; teacher and student roles)?

ii) if characteristics and conditions for effective science practice were present (e.g., reference to meaningful conceptual learning, interest and engagement of students; development of science enquiry skills; appropriate use of ICT)?

iii) whether other factors (e.g., teachers' beliefs) emerged from the data that were enabling (or obstructing) effective constructivist and inquiry-oriented science practice?

How do inferences from teacher feedback vary in relation to (i) and (ii):

- across different levels of Primary Connections units within the same content strand?
- across different content strands of Primary Connections units?

12.2 Conclusions and recommendations

12.21 General conclusion

A general conclusion that can be drawn from the overall project is that Primary Connections has had a very real, positive influence on most (if not all) responding teachers' thinking about the nature of inquiry-oriented and constructivist-based (as in, the 5E model) science learning at the primary level. It would appear that these perceptions have been realised, to varying degrees, in many classrooms. Furthermore, for some teachers, the influence of Primary Connections has produced teaching and learning environments that fulfil many criteria associated with high-quality science learning. There was, in many of these teachers' responses, a 'passion' for teaching science at the primary level, like for Hannah (in section 2.56); it 'oozed' through a range of their comments included in this report. This overall impression is significant, because for teachers to change their practice towards innovative science practices such as inquiry-oriented science and the use of the 5E learning cycle often takes in excess of a year (*see* section 2.51). It is plausible to suggest that the longer-term involvement in the Primary Connections program through the trial of one or more units and the provision of extensive written reflection is, in part, responsible for the impact on some of these teachers.

As a 'critical resource' that encourages teachers to persist in teaching constructivist and inquiry-oriented science is *to keep trying to teach in these ways*, then the findings from this project need to especially reach teachers who have made a 'start'. They, and teachers commencing their use of Primary Connections, need to see this style of teaching as a journey, not a destination: 'becoming science teachers' is a life-long professional process

Primary Connections has had a very real, positive influence on most (if not all) responding teachers' thinking about the nature of inquiry-oriented and constructivist-based (as in, the 5E model) science learning at the primary level. It would appear that these perceptions have been realised, to varying degrees, in many classrooms. Furthermore, for some teachers, the influence of Primary Connections has produced teaching and learning environments that fulfil many criteria associated with high-quality science learning.

(Carlone, Haun-Frank & Kimmel, pp. 956, 961; section 2.55). This report simply provides some further signposts on that journey in order to make it even more enjoyable and meaningful for teachers and their students.

This project has raised a number of issues for consideration by those involved with the professional learning of Primary Connections teachers, as well as those who develop support materials for Primary Connections. As the data have limitations, some of the recommendations may simply need further (straightforward) investigation to determine if they are being addressed; other recommndations clearly indicate issues that warrant inclusion in professional learning workshops and, possibly, support materials. The latter, for example, could be inserts within Primary Connections units. Inserts might provide reminders for teachers and/or a checklist of decisions and/or actions that need to be addressed or at least used as a basis for reflection and possible further action.

As stated, a key factor in teachers changing their beliefs and pedagogy about science teaching is the time they spend teaching a new approach, and their self-reflection and reflection with colleagues on their teaching. Consequently, some of the issues raised in this report could become the foci for productive discussion by Primary Connections teachers in their schools or at professional learning workshops. Several of these issues (and the detailed commentary about them in chapters 4 to 11) could also be used as illustrative material for discussion and related tasks; for example, there were some teachers who reported less positive responses to some of aspects of particular units—these comments would be of value for teachers to reflect on, and possibly discuss, different responses to a unit. The reflection and discussion could initially be open-ended and then use, as criteria, some of the attributes used to guide the analyses in chapters 4 to 10 to deepen the dialogue if necessary.

12.22
Enabling actions to help teachers implement Primary Connections units more effectively

The implications of the findings in this report for the future professional learning of Primary Connections teachers and the development of Primary Connections support material are presented below as '*enabling actions*', i.e., if taken, it is assumed that Primary Connections would be implemented more in line with its intentions. Some of the recommendations are a consequence of the comments of a minority of teachers[93], but their concerns may represent a larger number of teachers who do not regularly teach science and, hence, are still included. Monitoring of the effects of enacting the recommendations is advised.

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Recommendations that have been derived from the comments of a minority of teachers may be discerned from the detailed descriptions in chapters 4 to 11.

12.3 Responses to research questions: findings, insights and recommendations

In the following sections, the findings and insights related to each of the RQs are outlined. Recommendations that flow from these findings are then listed, providing a reference to the section of the report from which they derive.

12.31 Audiences for this report

This report and its recommendations are first and foremost for the Primary Connections team of professional learning leaders and the team that prepares curriculum support materials for Primary Connections. Many of the recommendations, when read in conjunction with the appropriate sections of the report, could become areas of focus in professional learning content and strategies and/or suggestions for written support materials. The recommendations, therefore, have a direct relationship to the actions primary teachers take when they are implementing Primary Connections and, hence, will impact on their students.

This report also will be of value to other (primary science) curriculum developers, in that it provides indicators on how to further improve the quality of primary science teaching with curriculum resources (and associated professional learning) that already have an established track record in many Australian schools. In that sense, the findings here and the consequent recommendations for improving primary science practice have gone beyond a superficial level. Primary Connections is already changing the face of primary science in a wide range of classrooms. Elements of student-centred constructivist learning and inquiry-oriented science are already happening in Primary Connections classrooms, and many students and their teachers are enjoying the experience, and both are learning (more science and more about learning science). This report provides numerous suggestions for ways to move this progression further forward. It can, therefore, assist other (primary science) curriculum developers, further advance their own initiatives.

Teacher educators could use this report to facilitate preservice teachers' analyses, and implementation, of Primary Connections materials, as well as draw upon the examples within the report for a range of teaching, learning and assessment purposes. Furthermore, the report provides detailed insights into practising teachers' thinking about the implementation of a curriculum resource.

This report provides substantial evidence that Primary Connections is engaging students and teachers in meaningful science learning that has caught their interest. Its recommendations suggest how to take this learning to another level. In that sense, it impacts on national priorities to improve the status of science in primary schools and, hence furthers, the Australian Government's and the Australian Academy of Science's goals for primary science education.

12.4 Implementing the 5E learning cycle: teacher understanding and practice*

12.41 The overall 5E model

Findings and insights

Overall, teachers and students enjoyed the Primary Connections units and student learning in science advanced (section 4.2). The units encouraged investigative

* Relates to RQ[i].

science (4.2 and 4.35) and, occasionally, autonomous student learning (4.3). Students' conceptual learning was enhanced by experiencing two consequential units from the same strand, and their SIS development by experiencing two or more units (4.26).

Some teachers:

- had reflected on the 5E model and were starting to base their lesson planning on it (4.32);
- indicated that their science pedagogy was changing (4.23).

Some teachers:

- deleted or omitted a 5E phase or phases (4.31);
- appeared to take some actions inconsistent with the purposes of a phase or phases (4.32).

Issues that challenged some teachers were:

- the need to focus on a key conceptual idea across the sequence (4.24);
- that the units were too long and time consuming (4.2 and 4.52).

Recommendations

Following from the above findings, it is recommended that, *in general*:

- Positive teacher perceptions of Primary Connections be made known to teachers.
- Examples of how teachers have planned their own units using the 5E model be made available for teachers ready to move to more autonomous 5E planning.

To enable teachers to implement Primary Connections more effectively, it is recommended that the following be considered as foci in professional learning and/or the development of support materials. These *specific* recommendations flow from the above findings. They are that:

- the overall key idea for a 5E sequence (a unit) be clearly identified (4.24);
- when student interest is followed, a return to the key idea is required (4.51);
- every phase in the 5E model is important for optimum learning; none are unnecessary and none should be omitted. The impact of omitting a phase needs to be pointed out (4.31);
- alternative pathways through units be suggested for teachers pressed for time, so that the integrity of the five phases is not lost (4.52);
- the *overall* purpose of each phase be understood, so that actions are consistent with the purpose; consider using a self-evaluation 'test' to check understanding (4.32 and 4.5);
- there be an indication that explicit teaching of SIS will be necessary at times, but that they will improve with scaffolded practice (4.25).

It could also be emphasised that teaching two or more units can improve students' conceptual and SIS learning outcomes (4.26).

12.5 The separate 5E phases: findings, insights and recommendations

Each of the 5E phases was separately analysed. Findings and insights are listed for each phase.

Overall, teachers and students enjoyed the Primary Connections units, and student learning in science advanced.

12.51 Phase 1—*Engage* phase

Findings and insights

- All the purposes of the *Engage* phase for most units were achievable with some of the teachers across a variety of contexts (5.1).
- Most units created interest and stimulated curiosity, with many identifying students' ideas and/or having students compare their ideas (5.1, 5.11).
- In relation to creating interest and stimulating curiosity, Primary Connections lessons have many built-in features that create interest and stimulate curiosity, and these were sometimes contrary to teacher expectation (5.11).
- In relation to identifying students' ideas and/or having students compare their ideas:
    - Teachers used a very wide variety of elicitation strategies, some of their own making (5.14).
    - There were some exemplary teacher comments that fully appreciated the role of eliciting students' ideas in the *Engage* phase (5.14).
    - Some teachers may need more advice on using some elicitation strategies, such as concept maps and concept cartoons, although they were used well by others (5.14).
    - Some teachers' comments were ambivalent as to whether they were helping students recognise their existing ideas (for later testing and/or reflection) or seeking 'correct' responses too soon (5.14).
- Students' questions were rarely raised for inquiry (5.1, 5.13).
- Setting learning within a meaningful context may have been assumed by many teachers to be met by the context described in the Primary Connections units, as few teachers mentioned that they explicitly drew other connections between the units' content and students' lives (5.1, 5.12).
    - Some Primary Connections units have built-in meaningful contexts that assist in creating situational interest.
    - Teachers held contrasting views about the relevance (i.e., the context) of some Primary Connections units.

Other findings and insights from the *Engage* phase were:

- Teachers can differ markedly on the balance required between the role of 'talk' (e.g., discussion and debate) and physical activity (5.11).

Recommendations

These recommendations flow from the above *Engage* phase findings.

To enable teachers to implement Primary Connections more effectively, the following may be considered as foci in professional learning and/or the development of support materials:

- Heighten teachers' awareness of strategies to raise student questions for inquiry and then assist them to identify those that will link with the purposes of later phases (5.13).
- Develop 'How to' approaches for how to handle students' questions, so that they can become the bases for future student activities (e.g., 'turning' student questions into questions that can be answered by using SIS) (5.13).
- Encourage teachers to explicitly link unit content and specific activities within units to students' everyday lives, and to do this beyond what Primary Connections units suggest (5.12).
- Explicitly encourage teachers to connect concepts (such as solids, liquids and gases or forces) to everyday experiences and events; for example, brainstorm such a task in professional development workshops (examples from section 5.12 could be used).
- Use the feedback of teachers related to the purposes of the *Engage* phase (and categorised in this research project) as a basis for learning about the *Engage* purposes (5.1).
- Advocate more strongly why Primary Connections includes as integral to its lessons student 'talk' (e.g., the role of discussion and dialogue as outlined in Chapter 8) (5.14).
- Reiterate that the *Engage* phase is for elicitation of students' ideas, and that they become the focus again in later phases; students' responses are not for correcting at this phase but for sharing and discussion (5.14).
- Revisit Primary Connections units where the data analyses indicate that teacher responses addressing *Engage* purposes were low, to ascertain if there are any reasons for the limited responses for that purpose (5.1 and 5.6).

12.52
Phase 2—*Explore* phase

Findings and insights

- All the purposes of the *Explore* phase were achievable for all units (with a possible exception of one purpose for one unit) with some of the teachers across a variety of contexts (5.2 and associated tables).
- All units provided experience of the phenomenon or concept, with many activities having a most positive impact on teachers and students (5.21).
    - There was one unit, for the youngest learners, where this purpose was reported as being met by only a few teachers (WW); the diversity of opinion between those that did and did not report meeting this purpose may be due to the diversity of student abilities at this level, but it could also suggest that younger students' abilities are underestimated (e.g., *see* Metz, 1998) (5.21).
- Discussion of the phenomena was regularly mentioned across units (5.22).

- Fair testing, when further details were mentioned, suggested rigorous application of this inquiry process (5.23).
- In some units, possibly topics that are very common in primary years such as seed germination and plant growth, teachers may only be encouraging a limited range of SIS, such as observing and recording (5.23).
- Testing *students*' ideas tended to be more common than exploring *students*' questions; lessons where this occurred often referred to students making predictions (5.22).
- Although exploring and inquiring into students' questions and testing their ideas was less common (than the other two *Explore* purposes), there were sufficient examples to indicate that *students*' ideas and questions can be the focus (5.22).
    - With the youngest students there appeared to be less focus on testing *their* ideas and exploring *their* questions (5.22).
- Investigating and solving problems, even if not the students', was present in most classes and was mentioned across all units by some teachers. In some units, it was most obvious (5.23).
- Some teachers indicated, at times, that they were very aware of the conceptual bases of the *Explore* activities, while others found this problematic (5.1 overall).
- Teachers' comments suggested at least eight reasons why the *Explore* phase was successful for most teachers, and four why it was less successful for some (5.24).
- There were many exemplary comments about the appropriateness of the activities in the *Explore* phase (5.1 overall).

Findings and insights that tended to be confined to one unit (EP):

- When there was a greater focus on NoS outcomes, then this may not have been recognised by some teachers, and where recognised, students often required additional scaffolding because the 'science' was different to what they may expect (5.24).

Recommendations

These recommendations flow from the above *Explore* phase findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Share with new Primary Connections teachers the feedback from teachers who have met the purposes of the *Explore* phase (5.2 overall).
- More alternatives may need to be included in units for the youngest learners to cater for the possible diversity of student abilities (5.21 and 5.22).
- Indicate a variety of strategies that encourage a focus on raising questions and ways to handle them as questions for SIS use, including investigation (5.24).
- Indicate the strength of particular strategies that encourage predicting, especially if reasons for predictions are included, as in the PROE approach; discuss other strategies with teachers that tend to encourage students to predict, such as before and after observations (5.22).
- Assist teachers to appreciate the difference between testing predictions and testing students' ideas for their predictions (5.22).

- Reiterate the various components of an enquiry (and, specifically, scientific investigations) that students can be invited to make decisions about, for example, the question, the predictions, the investigation plan and the way to collect data (5.21 and 5.23).
    - Use case study material/vignettes/extracts from this report to contrast how teachers have handled who makes the enquiry (investigation) decisions (the student, the teacher, the resource material). This suggestion, in part, asks how closed or open teachers' questions and comments should be in particular phases (*see* Chapter 7).
- Ensure that teachers are conscious that the SIS focus is not always limited to observing and recording (also *see* Chapter 7) (5.22 and 5.23).
- Consider using the EP case study in section 5.25 to raise issues about why some teachers were able to address *Explore* phase purposes in a unit (with an increased NoS focus) while others were less successful (5.24).
- In units where the focus may have been more on testing students' ideas than exploring their questions, investigate if there may be the need for more opportunities to encourage the exploration of student *questions* (5.22).
- Whether, with the youngest students, teachers need to be encouraged, perhaps with examples from other early primary years' teachers, that with scaffolding the questions and ideas to be explored and tested can still be the students' (5.22 and 5.23).

12.53 Phase 3—*Explain* phase

Findings and insights

- All the purposes of the *Explain* phase were achievable in all units (with a possible exception of one purpose for one unit) for some teachers within a variety of contexts (5.3).
- Teachers used a wide variety of conceptual tools across the units and some teachers used several conceptual tools to facilitate students' organisation of the main idea in their thinking (5.31).
    - Some teachers used a very limited range of conceptual tools (5.31).
- 'Evidence' as a concept may have been implied in several lesson, but indications were that its use was limited (5.31).
- Units which teachers and students said they enjoyed the most did usually align with teachers asking students to construct explanations in more than one mode (5.32).
    - Teachers in some units implied that students constructed explanations using one mode, or if two, then only talking and writing (5.32).
- Although discussion was regularly mentioned across most units, there was only a limited number of teachers' comments that referred to students comparing *their* explanations (5.33).
- The scientific explanation was evident across most units, and, in some cases, uppermost in several teachers' comments (5.34).

    - There may be units in which teachers were not clear what scientific view(s) were to be the focus; Primary Connections may need to ensure that they are clearly stated (5.34).
- Role-play and other kinaesthetic/haptic modalities received regular mention as helpful strategies to assist students in organising their thinking (5.31 and 5.32).

Recommendations

These recommendations flow from the above *Explain* phase findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Be very explicit about teachers using more than one conceptual tool to facilitate understanding of the key concept; this may be especially important if students are finding the concepts unfamiliar (as was the case with the 'forces' concept for some students) (5.31).
- Teachers, especially in upper primary years, explicitly introduce the concept of 'evidence' and help students to become familiar with its presence in science lessons (5.31).
- Teachers encourage students to construct explanations in more than one mode where this is readily feasible, and especially more than a verbal and/or written mode; this is especially useful when students are finding the concepts unfamiliar (5.32).
- Pose the question to teachers, 'What do they expect from discussion in the *Explain* phase?' Ensure teachers appreciate that students be given the opportunity to express their 'organisation' of the key concept developing from the earlier phases, and that students are able to compare explanations from each other (all of 5.3).

12.54
Phase 4—*Elaborate* phase

Findings and insights

- The main conceptual idea that was being used and/or applied in the *Elaborate* phase was rarely mentioned by teachers, but there were clear examples of the main conceptual idea that was being used and/or applied in a couple of units (5.41).
- Fair testing was a major focus in most units (5.41).
- Many teachers used and integrated a range of modes to assist students in reconstructing and/or extending their explanations.

Recommendations

These recommendations flow from the above *Elaborate* phase findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Primary Connections must ensure that the main conceptual idea to be used and/or applied be explicitly stated in the notes about this phase, and, if necessary, an explanatory comment added to assist teachers to 'see' the connection between the *Explain* and *Elaborate* phases (5.41).

- Teachers work with others, or at professional development workshops, through a couple of Primary Connections units to discern the main conceptual idea to be used and/or applied (5.41).
- Teachers need to distinguish between applying a fair test in a new context and applying a concept in a new context using a fair test investigation (5.41).
- Primary Connections make it explicit that teachers consider using several modes to help with the reconstruction of ideas, and not rely on the lesson steps in Primary Connections mentioning more than one mode (5.42).

12.55
Phase 5—*Evaluate* phase

Findings and insights

- Providing opportunities for students to review their conceptual learning tended to dominate in teachers' comments compared to opportunities for students to reflect on their learning (5.51).
- Reference by teachers to assessing SIS in a *summative* sense (in the *Elaborate* phase) were not discerned (5.51).
- Teachers did report that a wide variety of assessment processes were used to assess science understandings (5.51).
- There were fewer reports of teachers providing evidence for changes to students' understandings, beliefs and skills (5.52).

Recommendations

These recommendations flow from the above *Evaluate* phase findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Teachers ensure that students be given the opportunity to reflect on their learning and (especially their) learning processes (i.e., how they are learning) (5.41).
- Ensure that teachers appreciate the difference between assessing understanding and assessing knowledge (5.41).
- Where feasible, set Primary Connections assessment tasks within authentic contexts (5.41).
- Teachers consider how they can determine changes in students' levels of understanding across the time span of a unit (e.g., through students reporting on how their thinking has changed) (5.42).
  - To seek evidence of change requires elicitation of individual students' ideas in the *Engage* and *Explore* phases (5.42).
- As summative assessment of SIS is a goal in Primary Connections, ensure that there are lesson steps (and possibly suggested tasks at times) to meet this expectation (5.41 and Chapter 9).

12.6 Teacher understanding and implementation of constructivist and inquiry-oriented pedagogies*

* Relates to RQ[i].

12.61
Teaching with a constructivist emphasis

Findings and Insights

- The extent to which many teachers saw their role from a personal constructivist perspective, (i.e., helping students to be conscious of changing their own ideas) was problematic (Chapter 6).
- There was a very strong focus on the constructivist role of students learning actively (mentally and physically), although learning 'mentally' did occasionally appear impeded (6.2).
- There were ample examples of students discussing their own and others' ideas in all units; minimal difficulties were encountered (6.3).
- It was not always apparent that learners (and possibly their teachers) appreciated that the *Elaborate* phase was, in part, for learners to use ideas to try to understand new events/phenomena (6.4 and 5.4).
- There were not numerous examples to draw on related to reasoning about evidence (6.5).
  - A few teachers did use Primary Connections and their own strategies to focus on this learner role (e.g., Predict-Reason-Observe-Explain) (6.5).
  - Although there were several teachers aware of students' reasoning about 'evidence', there was doubt as to whether this was a key focus for them (and, hence, for their students). Of interest is that across all 16 units only two teachers used the term 'evidence' (6.5).
- It was difficult to identify teachers' comments that indicated students were modifying their ideas in the light of evidence; there were limited examples (6.6).
- Although probably not explicit in teachers' minds, several teachers did encourage students to develop 'bigger' ideas from 'smaller' ones (6.7).
  - In addressing these roles, there were examples of teachers finding out learners' ideas and skills by questioning, observing etc. (6.91); deciding on appropriate action based on learners' existing ideas and skills (6.92); and arranging for group and whole class discussion (6.93).

Recommendations

These recommendations flow from the above 'Constructivist emphasis' findings.

PC FINDINGS

Teachers' confidence to teach primary science appeared to be positively impacted by teaching Primary Connections units … which was, in part, related to their students' obvious interest in science and the impact of the units on their learning in science.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- From a constructivist perspective, ensure that the following three/four learner roles are explicit in teachers' thinking (6.4 to 6.7; 6.9):
  - using ideas to try to understand new events/phenomena;
  - reasoning about evidence and;
  - modifying ideas in the light of evidence.
- As 'evidence' is such a central concept in science education, there would be value in it being highlighted in all Primary Connections units, especially as it relates to modifying ideas (6.6).
- Developing 'bigger' ideas from 'smaller' ones.
  - Consider using extracts from Chapter 6 to illustrate how some teachers have encouraged these learner roles.
- Encourage teachers to reflect on why they use group and whole class discussion from a constructivist perspective (6.9).

12.62
Teaching with an inquiry emphasis

Findings and Insights

- Overall, there was a strong inquiry orientation during the implementation of the Primary Connections units (7.6).
- All students often collected data (evidence) (first hand and from secondary sources) about the world around and were learning actively (physically and usually mentally); all students were reporting/recording what they observed (7.2 and 7.4).
  - When students recorded electronically this seemed to heighten motivation (7.4).
- Students regularly used science inquiry skills, especially observation, prediction, recording and fair testing (7.3, 7.31–7.33).
  - It was less common for teachers to state that some other inquiry skills were used, such as classifying, hypothesising (giving reasons for predictions) and evaluating the data they had collected (7.3).
  - Guided investigations (mainly fair testing) were far more common than open investigations (7.33); fair testing usually needs initial scaffolding (7.7).
  - Many students appear to appreciate fair testing on its first use and improve in their approaches to fair testing with experience, but it cannot be assumed that this will be similar for all teachers and their classes, and across all content areas (7.33, 7.7).
- Assessment of SIS did occur, but it was not regularly mentioned (compared to assessment of conceptual outcomes) (7.5).
- It was not readily apparent that teachers were seeking evidence from students in order to relate observations to their interpretation (7.4).

Recommendations

These recommendations flow from the above 'Inquiry emphasis' findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Encourage teachers to be alert to the range of SIS that they are encouraging their students to use; where feasible, consider the value of using ICT when using some of these skills (7.3).
- The concept of 'evidence' be explicitly introduced by middle and upper level teachers, especially how it connects various components of the investigation process (7.4).
- The value of sharing and discussing with teachers some of the exemplary examples of fair testing and the use of various SIS in Chapter 7 (and section 5.4).
- Indicate feasible ways that teachers can assess SIS in a summative sense (7.5).

12.63
Teaching with a language emphasis

Findings and Insights

- In general, (science) 'language/talk' was emphasised by most teachers, although the different forms it took were practised more by some teachers than others (all of Chapter 8).
- Discussion was a regular feature in all classrooms (albeit limited at times with some of the youngest learners) (8.31); 'Dialogue' and 'Argumentation' were also present, but to what extent, was more problematic (8.32, 8.33).
- Students explaining ideas and listening and responding to others was facilitated by many actions teachers took (8.34).
- Teachers were alert to the importance of using language appropriate for explaining scientific phenomena and provided many examples (8.4).
    - Most teachers that referred to the word wall and the science journal complimented their value to learning (8.41).
- There were examples of teachers using two teacher roles to encourage students to use language/talk in their science learning: these were acknowledging students' ideas in a way that values them, and asking for examples to clarify students' ideas. However, it was not possible to discern if teachers modelled skills of using talk productively (6.6).

Recommendations

These recommendations flow from the above 'Language emphasis' findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Different ways that language/talk can be used in science learning be explicitly identified for teachers, with examples (Primary Connections units could be the focus of an analytical task where teachers are asked to identify where discussion, dialogue and argumentation is encouraged or could occur) (8.3 and 8.4).
- Ways and examples of how teachers could model skills of using talk productively be included (8.6).

*
Relates to RQ[ii].

12.7 The presence of characteristics and conditions for practice in science*

12.71
Teaching with an assessment focus

Findings and insights

Findings, insights and recommendations related to summative assessment of conceptual outcomes are found in section 12.55 (Phase 5: *Evaluate* phase). Other findings and insights are:

- In broad terms, in a majority of classes across most units, assessment is embedded within the science learning strategy.
- Primary Connections has enabled many teachers to engage in assessing their students' progress in science.
  - Some teachers were very alert to assessment of student learning (9.4, 9.5).
  - Some teachers directly related assessment to learning outcomes (9.42).
  - Teachers are using a wide variety of assessment processes (9.7).
  - There are indications that some teachers have developed confidence to assess science learning outcomes (9.3).
- Finding adequate time for separate assessment tasks was a challenge for some teachers (9.43).
- Diagnostic assessment was present when teachers determined students' existing conceptions; there were several examples of this happening (9.2 and 5.14).
- Teachers often did refer to formative assessment of conceptual understanding and, to a lesser extent, development of SIS (9.7).
- As a component of formative assessment teachers very rarely referred to:
  - students' self and peer assessment in science;
  - encouraging students to contribute to discussion about the standards of quality to apply in assessing their work and that they take responsibility for working towards the goals of particular activities (9.73).

Recommendations

These recommendations flow from the above 'Assessment emphasis' findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Ensure teachers provide opportunities for students to reflect on (not just review) their learning, and especially their experiences of their learning processes (9.6).
- Build into units and/or raise awareness of additional learner roles in formative assessment, namely, self and peer assessment in science, encouraging students to contribute to discussion about the standards of quality to apply in assessing their work and that they take responsibility for working towards the goals of particular activities (9.73).

- Share experienced Primary Connections' teachers' assessment processes with teachers commencing the program (Chapter 9).

12.72
The presence of SiS components for the effective learning of science

Findings and insights

There are eight SiS components. 'Assessment' findings and recommendations are outlined above. Catering to individual students' needs and preferences is a component that is very context dependent; findings and insights for this component are not listed here and it is not appropriate to make recommendations (*see* 10.7 for details).

With reference to the other seven components, the findings indicated that:

- Some were met in a majority of classes across all units, namely:
  - Students are encouraged to actively engage with ideas and evidence.
  - Students are challenged to develop meaningful understandings.
  - Science is linked with students' lives and interests.
- Some were met in a majority of classes, usually in a significant minority of units, namely:
  - Students' individual learning needs and preferences are catered for.
  - NoS (how science works) is represented in its different aspects.
  - The classroom is linked with the broader community.
  - Learning technologies are exploited for their learning potentialities (10.3).

Findings and insights related to each separate component were:

- All students actively engaged with ideas, and there were examples of engaging with evidence across many units, but it was not mentioned as regularly as engagement with ideas (10.41).
- There were some exemplary examples of engaging with evidence, with some teachers using novel strategies (10.42).
- Fair testing provided a ready opportunity for middle and upper primary teachers to explicitly introduce the concept of evidence (10.42).
- The development of meaningful conceptual understandings was obvious in the *Explain* phase of many units (10.51), although teachers did not always make it explicit (10.5, and 10.51).
- Although SIS were, in general, regularly applied, the development of meaningful process understandings and understandings about the NoS were less common (10.52).
- For some units, teachers held contrasting views about the development of meaningful understandings (e.g., the role of students sharing their explanations) (10.53).
- Many, but not all, Primary Connections units related directly or indirectly to students' lives and interests, and teachers may not have added to this inclusion (10.61).

- Some teachers explicitly added further links between Primary Connections units and students' lives and interests, and this took a range of forms (10.62–10.67).
  - A few teachers did not appear to make such links if Primary Connections units did not implicitly attract students' attention by making links with their lives and interests.
  - Examples of the initiatives shown by some teachers in linking units to students' lives and interests be shared with other teachers.
- Examples of links between Primary Connections units and the wider community were present in most, but not all units. Many of the examples were initiatives taken by individual teachers, but in most units there were only one or two teachers who referred to these outside links (10.8).
- Many teachers made comments about NoS attributes in their lessons, but explicit teaching about the characteristics of the NoS was probably rare (10.92);
  - Primary Connections provides numerous opportunities for teachers to make NoS explicit for students; this may have occurred in some of the examples cited (10.92–10.94).
  - The unit which most explicitly refers to a less common NoS attribute encountered at the primary level (EP), namely, the representation of learning through mental and physical models, was appreciated by some teachers and their students but less so by others (10.93).
- ICT use varied considerably across units (from no examples to five teachers in one unit). Although some teachers referred to standard ICT uses (e.g., accessing a website), there was still quite a variety of ICT uses (e.g., a microscope with computer interface), but at times it was the same teacher using several ICT forms (10.10).
  - Occasionally, some teachers experienced problems with recommended Primary Connections websites (but others did not); this caused frustration for some teachers (10.10).

Recommendations

These recommendations flow from the above 'SiS component' findings.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- The concept of evidence be made explicit for middle and upper primary classes; examples of where and how it could be introduced be shared with teachers (10.42).
- Teachers be alert to opportunities for students to engage with meaningful process and NoS understandings (10.52).
- For every Primary Connections unit, all teachers need to make explicit links between students' lives and interests (10.6).
- Teachers be encouraged to make links between Primary Connections units and the wider community wherever feasible; examples from Primary Connections teachers (e.g, as in this report) be made known to other teachers (10.81–10.84).
- Teachers become aware of the nature of NoS attributes appropriate at the primary level (10.9).
  - Teachers take the many NoS opportunities that Primary Connections provides to make NoS explicit for their students (10.92–10.93).

    - Encourage teachers to engage their students with the representation of learning through mental and physical models, albeit a relatively 'new' area for them; this may require students to 'see' a different side of science that can be creative (10.93).
- Additional examples of how ICT could become the '6th E' be made available to teachers across all year levels (10.10).
    - The potential impact of electronic journals be emphasised (10.10).

12.8 Other factors facilitating or hindering effective constructivist and inquiry-oriented science practice

Responses to this RQ are of a different nature to those for RQs (i) and (ii).

Findings and insights

- Teachers' confidence to teach primary science appeared to be positively impacted by teaching Primary Connections units (11.31), their enjoyment in teaching Primary Connections units (which was, in part, related to their students' obvious interest in science and the impact of the units on their learning in science) (11.32), and the Primary Connections science background sections (11.34).
- Teachers' comments indicated that they held beliefs about science (11.21), scientists (11.22), appropriate content and concepts in science for primary learners (11.23) and pedagogy in science (11.24). These beliefs varied considerably across teachers in this project.
- Virtually all teachers who commented on the literacy aspects of Primary Connections commended their inclusion (11.4 and 11.41); the potential of Primary Connections units to link with other curriculum areas was also very positively received (11.42).
- For most teachers, Primary Connections does not appear to interfere with being able to meet system requirements, but this was not the case for all teachers (11.51, 11.52).
- Different teachers encountered a relatively small number of obstacles in implementing Primary Connections units. The most commonly mentioned were time and ease of access to equipment and materials, together with preparation of the materials (11.54 and 11.55). This was not the case for all units, or for all teachers. Other obstacles, for a few teachers, were students not having pre-requisite skills (11.62).
    - Two impediments that may impact on the most effective implementation of Primary Connections are teachers' possible lack of familiarity with key pedagogical language (11.53) and broad underpinnings of constructivist learning (11.51). These impediments are speculative and may not be influential.

Recommendations

These recommendations flow from the above findings that emerged from the teachers' comments.

To enable teachers to implement Primary Connections more effectively, the following be considered as foci in professional learning and/or the development of support materials:

- Share with beginning Primary Connections teachers some of the impacts that teaching Primary Connections units has had on other teachers (11.31–11.34).
- Assist teachers to recognise their beliefs about science (11.21), scientists (11.22), appropriate content and concepts in science for primary learners (11.23) and pedagogy in science (11.24), and encourage them to reflect on the impact of their beliefs on their teaching, as well as how they interact with their students and their students' learning in science.
- Engage teachers in reflecting about whether their beliefs about science (11.21), scientists (11.22), appropriate content and concepts in science for primary learners (11.23) and pedagogy in science (11.24) are consistent with or contrary to the inherent beliefs about these areas in Primary Connections.
- Ask teachers for reasons why science should link with other curriculum areas; pose the question whether it has anything to do with how they 'see' science in their day to day lives (11.4).
- Provide exemplars from other Primary Connections teachers about how they have met literacy, numeracy and other curriculum area learning outcomes by linking Primary Connections to these areas (11.4).
- Provide options for how teachers can complete Primary Connections units in shorter time periods by selecting pathways through the units that do not affect the integrity of the 5E model.
- Teachers be encouraged to raise any foreseeable problems with the implementation of Primary Connections, and discuss various solution options with colleagues (11.6).

12.9 Variations in teacher responses across different content strands and levels of Primary Connections units

A survey of tables 5.9 and 10.2 suggests there were no obvious patterns related to the attributes mentioned in research questions (i) and (ii). Some speculative possibilities are advanced in relation to Table 5.9 (*see* section 5.6). As stated there, if the discussion resonated with Primary Connections leaders, then there may be reason to reflect further on the strands and levels and details within Chapter 5. One unit that very few teachers indicated met a range of the criteria used in this report was WW. It is discussed in the report (in various places).

12.10 Conclusion

Primary science has moved forward considerably in the last two decades, often because of research initiatives such as the Science in Schools project (Tytler 2003) and those associated with Primary Connections (e.g., Hackling 2008; Hackling & Prain 2005, 2008). This report has found that Primary Connections has had a real and positive impact on many teachers who have trialled its units and reflected on those trials. This report, with its focus on the teacher, has raised possible areas for further action. In *Re-imagining science education for Australia's future*, Tytler states:

> Teachers are the key to how and what students learn in their science classes, and any attempt to re-imagine the science curriculum must involve serious attention to teacher learning. (Tytler, 2007, p. 67)

This report will assist in that re-imagining.

Primary Connections has had a real and positive impact on many teachers who have trialled its units and reflected on those trials.

Abbreviations

AAS	Australian Academy of Science
ASS	All sorts of stuff
ACARA	Australian Curriculum, Assessment and Reporting Authority
COGS	Connected Outcome Groups
CBATS	Context Belief About Teaching Science
CD	Change detectives
EC	Electric circuits
EP	Earth's place in space
ES1	Early Stage 1
ICT	Information and Communications Technology
ISS	International Space Station
IWB	Interactive Whiteboard
KLA	Key Learning Area
MMat	Material matters
MM	Marvellous micro-organisms
NAPLAN	National Assessment Program—Literacy and Numeracy
NoS	Nature of Science
OTM	On the move
PA	Plants in action
PAB	Personal Agency Belief
PP	Push-pull
PL	Professional Learning
POE	Predict-Observe-Explain
PROE	Predict, Reason, Observe and Explain
RQs	Research Questions
RS	Resource Sheet
SHE	Science as a Human Endeavour
SiS	Science in Schools
SIS	Science Inquiry Skills
STEB	Science Teaching Efficacy Belief
TSD	Traditional Schooling Discourse
TWLH	Think Want Learned How
S1	Stage 1
S2	Stage 2
S3	Stage 3
SA	Staying alive
SD	Spot the difference
SM	Smooth moves
SS	Spinning in space
SZ	Schoolyard Zoo
WM	What's it made of?
WW	Weather in my world
Ww	Water works

References

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Appendices

2.1 Purposes of the phases in the 5E learning cycle (AAS, 2008a)

Engage

- Create interest and stimulate curiosity.
- Set learning within a meaningful context.
- Raise questions for inquiry.
- Reveal students' ideas and beliefs, compare students' ideas.

Explore

- Provide experience of the phenomenon or concept.
- Explore and inquire into students' questions and test their ideas.
- Investigate and solve problems.

Explain

- Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon.
- Construct multi-modal explanations and justify claims in terms of the evidence gathered.
- Compare explanations generated by different students/groups.
- Consider current scientific explanations.

Elaborate

- Use and apply concepts and explanations in new contexts to test their general applicability.
- Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics.

Evaluate

- Provide an opportunity for students to review and reflect on their own learning and new understanding and skills.
- Provide evidence for changes to students' understanding, beliefs and skills.

2.2 Learner and teacher roles from personal and social constructivist perspectives, as well as inquiry skill and assessment perspectives (Harlen, 2009)

From a personal constructivist perspective

Learners' roles

- Learning actively (mentally and physically).
- Discussing own and others' ideas.
- Using ideas to try to understand new events/phenomena.
- Reasoning about evidence.
- Modifying ideas in the light of evidence.
- Developing 'bigger' ideas from 'smaller' ones.

Teachers' roles

- Making provisions for the learners' roles.
- Finding out learners' ideas and skills by questioning, observing etc.
- Deciding on appropriate action based on learners' existing ideas and skills.
- Arranging for group and whole class discussions.

From a discussion, dialogue and argumentation perspective

Learners' roles

- Explaining their own ideas to others with examples where appropriate.
- Using language appropriate for explaining scientific phenomena.
- Listening and responding to others' ideas.
- Defending their ideas using evidence.

Teachers' roles

- Modelling skills of using talk productively.
- Acknowledging students' ideas in a way that values them.
- Asking for examples to clarify students' ideas.
- Expecting students' to support their claims or ideas with evidence.

From an inquiry perspective

Learners' roles

- Collecting evidence (first hand and from secondary sources) about the world around.
- Using inquiry skills (observation, prediction etc.).
- Learning actively (mentally an physically).
- Reporting and discussing evidence.
- Reasoning with others about how different ideas fit the evidences (argumentation).
- Reflecting on learning processes and outcomes.

Teachers' roles

- Making provisions for the learners' roles.
- Arranging for group and whole class discussions.
- Encouraging the use of inquiry skills through questioning.
- Providing time for reflection on learning.

From a formative use of assessment perspective

Learners' roles

- Taking responsibility for working towards the goals of particular activities.
- Agreeing on the standards of quality to apply in assessing their work.
- Participating in self assessment and identifying their next steps.
- Participating in peer assessment.
- Reflecting on learning processes and outcomes.

Teachers' roles

- Making provisions for the learners' roles.
- Identifying progression towards both short- and long-term goals of learning.
- Providing feedback that advises learners on how to improve or move on.
- Using information about learners' progress to regulate teaching.
- Providing the amount of challenge that promotes learning.

(Harlen, 2009, p. 40)

2.3 SiS conditions that support effective student science learning (Tytler, 2003)

1 Students are encouraged to actively engage with ideas and evidence.

Students are encouraged to express their ideas and to question evidence in investigations and in public science issues. Their input influences the course of the lessons. They are encouraged and supported to take some responsibility for science investigations, and for their own learning.

2 Students are challenged to develop meaningful understandings.

Students are challenged and supported to develop deeper understanding of science ideas and to connect and extend ideas across lessons and contexts. They are challenged to develop higher-order thinking, and to think laterally in solving science-based problems.

3 Science is linked with students' lives and interests.

Student interests and concerns are acknowledged in framing learning sequences. Links between students' interests, science knowledge and the real world are constantly emphasised.

4 Students' individual learning needs and preferences are catered for.

A range of strategies is used to monitor and respond to students' different learning needs and preferences, and their social and personal needs. There is a focused and sympathetic response to the range of ideas, interests and abilities of students.

5 Assessment is embedded within the science learning strategy.

Monitoring of student learning is varied and continuous, focuses on significant science understandings, and contributes to planning at a number of levels. A range of styles of assessment tasks is used to reflect different aspects of science and types of understanding.

6 The nature of science is represented in its different aspects.

Science is presented as a significant human enterprise with varied investigative traditions and constantly evolving understandings, which also has important social, personal and technological dimensions. The successes and limitations of science are acknowledged and discussed.

7 The classroom is linked with the broader community.

A variety of links is made between the classroom program and the local and broader community. These links emphasise the broad relevance and social and cultural implications of science, and frame the learning of science within a wider setting.

8 Learning technologies are exploited for their learning potentialities.

Learning technologies are used strategically for increasing the effectiveness of, and student control over, learning in science. Students use ICT in a variety of ways that reflect their use by professional scientists.

(Tytler 2003, p. 285)

2.4 The four strands of 'science as practice' (Harris & Rooks, 2010)

1 Know, use and interpret scientific explanations

This occurs when students have opportunities to apply ideas in scientific activity, use ideas to explain and predict phenomena, and make connections between ideas.

2 Generate and evaluate scientific evidence and explanations

This focuses on the important role of evidence as part of scientific practice … it focuses on designing and conducting investigations, analysing data and using evidence to draw conclusions, support arguments …. A central component of this strand is building and refining models and explanations based on evidence.

3 Understand the nature and development of scientific knowledge

This focuses on students' understanding of how scientific knowledge is constructed, including their own ideas about the natural world. This strand emphasises reflection—students are more likely to deepen their understanding of scientific knowledge and its nature when they have opportunities to experience science as practice, and reflect on their own ideas (and the ideas of others) as they generate evidence, learn new facts, and develop new models and explanations.

4 Participate productively in scientific practices and discourse

This is concerned with creating a science learning community in the classroom that mirrors a scientific community …. [IT] emphasises the importance of participation for learning the norms of science, including how to represent ideas, use scientific tools, and interact with peers in the scientific community of the classroom.

(Extracts from Harris & Rooks 2010, p. 229)

2.5 The nature of pervasive management: description and some issues (Harris & Rooks, 2010)

Students

Inquiry instruction places higher demands on students in terms of participation, personal responsibility for learning, and intellectual effort .... Students are expected to 'talk science'... as they work together to plan and carry out investigations, and engage in discussion and debate with each other and the teacher. This shift in classroom expectations can be overwhelming for many students, especially those who have limited science experience, content knowledge, and familiarity with inquiry skills .... Teachers need to help students develop the skills and stance necessary for engaging in inquiry .... Scaffolding is critical ....

Instructional materials

Following lesson descriptions step-by-step may not directly translate to success in inquiry classrooms .... A concern arises when teachers adopt the superficial features of an inquiry-based approach (and materials) and fail to take on the instructional stance required to fully support learning.

[An aspect of instructional materials is] managing technology to support student learning .... Increasingly, students are using the same technology tools that are used by practicing scientists. Observational research has shown that teachers can quickly become preoccupied with troubleshooting technology problem ... leaving little time to attend to students' thinking and learning while students are using the technology. Teachers need technology expertise, including knowledge of how to use and maintain the technology, as well as the pedagogical knowledge of how to use the technology with students to leverage learning.

Tasks

Authentic tasks in inquiry classrooms engage students in scientific activity in a manner similar to how scientists conduct their work, but in ways that are appropriate and meaningful for students and with carefully structured support.

Teachers need to carefully sequence activities so that students acquire the appropriate skills and knowledge as they work over time. Furthermore, effective participation in authentic tasks often involves solving problems in which there are no quick and easy solutions. Students can become discouraged with the difficulty of completing tasks. If teachers are to use authentic tasks effectively, they must address the challenges of organising instruction and supporting students.

Two important components are providing purpose and making clear the learning goals for tasks. *Providing purpose* supports the process of learning by making public the underlying reasoning for tasks. Students need to be aware of the purpose behind tasks if worthwhile learning is to be achieved.

Science ideas

Effective inquiry instruction requires that teachers create a series of coherent learning experiences that help students to build understanding of scientific ideas over time … building and sustaining coherence within and across lessons. The unfolding of a lesson during instruction creates a story line that can help students follow the logic of the lesson. A challenge for teachers is to create a comprehensible story line for students to follow and make sense of the learning experience ….

Another important aspect of managing science ideas is eliciting students' prior knowledge and previous experiences.

… [W]hen connections are made between science and students' own backgrounds, everyday experiences, and interests, students are more likely to find value and meaning in their classroom science tasks and activities.

… requires ongoing and active assessment of students' thinking and ideas during instruction.

Teachers often find themselves monitoring students during group work to ensure that students are on task and on pace for completing work, leaving little time to address the science ideas meant to be at the forefront of investigations …

The overall social context of students' inquiry learning environment

A classroom learning community describes a situation where teachers and students are engaged in a collective process of learning that produces shared understandings …

… The idea [is to] create a learning community with a shared purpose of making sense of scientific ideas and practices …

Management actions that lend to a comfortable and respectful environment include teachers relating to students and promoting students relating to each other; expecting attention and participation; being accepting of students' responses; encouraging and communicating respect for students' questions and ideas; and holding students accountable for doing class work.

(Extracts from Harris & Rooks, 2010, pp. 232–236)

2.6 A list of Nature of Science (NoS) attributes (Akerson, Buck, Donnelly, Nargundi-Joshi & Weiland, 2011)

Science:

- as tentative but robust;
- as subjective (theory-laden);
- as culturally embedded;
- as creative and imaginative;
- is based on empirical evidence;
- is a product of observation and inference;
- distinguishes between theories and laws.

2.7 Some teacher misconceptions about the learning cycle (Odom & Settlage Jr., 1996)

For the *Explore* phase

The teacher:

- 'demonstrates and explains a basic science concept because the teacher must provide a mental framework for the students before they begin exploring';
- 'explain(s) the concept prior to investigation because students should be told why and what they are investigating so they will understand the reason for the activity'; and
- 'has the responsibility of providing the scientific terms when the students are confused'.

(p. 132)

For the *Explain* phase

- 'Students should be allowed to explore data and terms freely; teacher intervention is not necessary'.

(p. 133)

For the *Elaborate* phase

- This was 'an opportunity for students to extend their understanding of a science concept to a new science concept'.

(p. 133)

Appendices

4.1 Teacher perceptions of strengths and weaknesses of Primary Connections units[1]

Unit	N[2]	Strengths	N[3]	Weaknesses
Weather in my world ES1	8	▪ Captured teacher interest (18); ▪ Captured student interest (5, 14); ▪ Appealing ideas/ activities (5,12); ▪ Links to students' world (9); ▪ Good progression (11); ▪ Impact on learning (14); ▪ Hands-on (14).	7(4)	▪ Lessons long (10); ▪ Unit long (5,11); ▪ too advanced for K/prep (4, 7,10); ▪ Too much passive activity (11,12); ▪ Inappropriate literacy level links (11).
Water works S1[4]	6	▪ Captured teacher interest (7); ▪ Captured student interest (4,8,9,12); ▪ Strong literacy links (4); ▪ Good progression (4,17); ▪ Hands-on (4); ▪ Good KLA potential (7,8,12); ▪ Impact on student learning (12).	1(0)	▪ Too long (17).
Spinning in space S2	8	▪ Captured teacher interest (UK, 13,16,19); ▪ Suitable length (1,15); Suitable variety of activity type (1); ▪ Good progression (2); ▪ Appreciated focus on one key idea (15); ▪ Flexible unit (15); ▪ Encourages student autonomy (16).	5(4)	▪ Did not capture student interest (4); ▪ Lacked cohesiveness (4); ▪ Did not appreciate focus on one key idea (11); ▪ Concepts too difficult/ abstract (11).
Earth's place in space S3[5]	5	▪ Captured teacher interest (9,15); ▪ Captured student interest (9); ▪ Good literacy connections (2,15); ▪ Hands-on (8); ▪ Impact on student learning (8).	10 (6)	▪ Unit too much content (5, 9, 15); ▪ Complex concepts (2); ▪ Practical illustration of concepts difficult (2); ▪ Difficulty of night observations (8); ▪ Inability of students to appreciate role of mental and physical models (9, 12, 13); ▪ Wider content scope needed (11); ▪ Impact on student learning problematic (13); ▪ Did not meet student expectations of a space unit (13).

1
Reasons are only included if they refer to the unit as a whole.

2
N is the number of teachers who mentioned a strength or a weakness.

3
Number in parentheses are teachers who did not include strengths.

4
The *Explain* lesson in the trial version (L6) became an *Elaborate* lesson in the final version. L6 (Investigating water use at home) and L7 (Water in other places) are reported here.

5
Moon and star observations were in the EP unit, but teacher comments did not comment on these except that some said they had difficulty getting students to complete this home task. Some classes did 'observe' computer simulations, but these are not recorded in the table. Most teachers reported that students made orreries (albeit several with equipment issues) but very few made mention of how they could have been used to 'test' student ideas about celestial movements.

What's it made of? ES1	5	▪ Captured teacher interest (1,7,8); ▪ Captured student interest (1,10); ▪ Suitable literacy demands for special needs students (1);	4	▪ Too long (8); ▪ Beyond student skill level (8).
Material matters S1	4	▪ Captured teacher interest (2,6, 11); ▪ Captured student interest (2,11); Appropriate length (2); ▪ Consistent with school context (2,5); ▪ Impact on student learning (11); ▪ Practical (11).	10 (8)	▪ Did not capture teacher interest (7); ▪ Did not capture student interest (7); ▪ Too much in lessons (2); ▪ Unit (3,5); ▪ Excessive teacher talk/ explanation (4,5); ▪ Needs more inquiry/ investigations (5,6); ▪ Disjointed concept development (7); ▪ Low impact student learning (9, 10); ▪ Unable to see everyday relevance (10).
All sorts of stuff S2	15	▪ Captured teacher interest (5,6,9,11,15,16,21,22); ▪ Captured student interest (6,9,15,16,20,21,22); ▪ hands-on (6); ▪ KLA potential (6,21); ▪ Impact on student learning (6,11,14,15,16,18,20,21, 22); ▪ Increased autonomy of student learning (22) appreciated investigations/fair testing inclusion/impact (11,18,21); ▪ Good balance of activity and reporting (13)	6 (3)	▪ Lessons too long (4,6,20); ▪ Lesson steps too detailed (6); ▪ Did not capture teacher interest (8); ▪ Equipment/materials not easily accessed (12); ▪ Not consistent with state syllabus (7).
Change detectives S3[6]	6	▪ Captured teacher interest (1,6, 8, 9); ▪ Captured student interest (1,2, 3, 8, 9,10); ▪ Students loved investigations (2, 9); ▪ Very 'practical' (6); ▪ Experiments simple (8); ▪ Applications clear (6); ▪ Equipment accessible (8); ▪ Impact on learning (8, 9, 10); ▪ Effective investigations [from student and teacher perspective] (8, 10).	5 (1)	▪ Unit too long (8, 9); ▪ Lesson too long (8, 9); ▪ Stronger literacy links needed (9); ▪ Different sequence suggested (10).

6
The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of *Change detectives* S3. Lesson 6 in the draft version is the basis for the data reported here.

On the move ES1	5	▪ Captured teacher interest (1,3); ▪ Captured student interest (1,3, 4, 8,6); ▪ Strong literacy connections (4); ▪ Good variety in types of activities (4); ▪ Impact on student learning (6).	0	
Push-pull S1	2	▪ Excellent sequencing (2); ▪ Hands-on (11); ▪ Extends high achievers (11).	4	▪ Unit/lessons too long (3, 6,8); ▪ Needed more teacher background (3); ▪ More guidance with 5E model needed (3).
Smooth moves S2	4	▪ Captured teacher interest (1, 10); ▪ Made difficult concept accessible (1); ▪ Captured student interest (2, 10); ▪ ICT enhanced unit (6); ▪ Encouraged home–school connections (6).	4 (3)	▪ Did not capture teacher interest (3,4); ▪ Concepts too easy or too difficult (4); ▪ Did not capture student interest (7); ▪ Time consuming [discussion + investigations] (10).
Electric circuits S3	4	▪ Captured student interest (5, 18); ▪ Problem solving approach (5); ▪ Captured teacher interest (15,16,18); ▪ Length suitable (15); ▪ Strong literacy links (18); ▪ Potential for KLA links (18).	2	▪ Questioned sequencing (6); ▪ Too simple (12).
Staying alive ES1	3	▪ Captured student interest (2,7); ▪ Impact on student learning (2); ▪ Students enjoyed investigations (2); ▪ Captured teacher interest (3).	2(1)	▪ Too long (1); ▪ Students had difficulty following flow of content (7).
Schoolyard zoo S1	9	▪ Captured student interest (7,9); ▪ Captured teacher interest (1,9,11,13, 14); ▪ Lots of hands-on (13); ▪ Appropriate amount of content (1); ▪ Positive impact on students (2).	4 (1)	▪ Too many literacy foci (3); ▪ Invertebrate activities inappropriate (3); ▪ Time consuming (11); ▪ Lessons too long (11); ▪ More ICT needed (17).

Plants in action S2	8	▪ Captured student interest (4,5,7); ▪ Teacher resources helpful (2,6); ▪ Strong literacy links (2); ▪ Good cross curriculum potential (2); ▪ Assisted teacher pedagogy (5); ▪ Encouraged teacher–parent contact (5); ▪ Allowed for diverse learning styles (6); ▪ Student autonomy in learning encouraged (6); ▪ Captured teacher interest (11); ▪ Most aspects 'worked for the students' (11).	6 (3)	▪ Unit too long [too many activities] (4,5,7,10); ▪ Too time consuming (5,10, 21); ▪ Repetitions in places (4,6).
Marvellous micro-organisms S3	12	▪ Captured student interest (2,5,12,17,19,23,25); ▪ Investigations/ experiments/ observations caught student interest (12,17,25); ▪ Students made investigation decisions (e.g., predict & test) (19); ▪ Captured teacher interest (2,3,8,9,10, 24); ▪ Good 'pace' (3); ▪ More 'science' (3); ▪ Relevant (23); ▪ Extended gifted students (23).	5 (2)	▪ Gathering resources/ equipment time consuming (2,7); ▪ Too many lessons (UK); ▪ More variety needed in teaching strategies from unit to unit (5); ▪ Link more to environment (6).
Total	104			

4.2A Teacher perceptions of strengths[1] of Primary Connections units

Unit/Strengths[2]	WW	Ww	SS	EP	WM	MMat	ASS	CD	OTM	PP	SM	EC	SA	SZ	PA	MM	Total
Captured T interest	1	1	4	2	3	3	8	4	2	0	2	3	1	5	1	7	47 (45%)
Captured S interest	2	4	0	1	2	2	7	6	5	0	2	2	2	2	3	6	46 (44%)
Positive impact on S learning	1	1	0	1	0	1	9	3	1	0	0	0	1	1	1	0	20 (20%)
Hands-on/practical	1	1		1		1	1	1		1				1			8
Good progression	1	2	1							1							5
Strong literacy links		1		2	1				1			1			1		7
Cross-curriculum potential		3					2					1			1		7
Suitable length/pace/ amount of content			2			1						1		1		1	6
Variety of activity type/ cater to learning styles			1				1		1						1		4
T/S appreciated investigation/fair testing/ observations impact							3	4					1			3	11 (10%)
Encourages S autonomy/S make investigation decisions			1				1								1	1	4
Appealing activities/ ideas	2																2
Consistent with school context						2											2
Flexible unit (follow S interest)			1														1
Links to S world/ relevant	1															1	2
Appreciated focus on key ideas			1														1
Equipment accessible								1									1
Applications clear								1									1
Extends high achievers										1						1	2
Difficult concepts accessible											1						1
ICT enhanced unit											1						1
Encouraged home–school connections											1				1		2
Problem solving approach												1					1
Valued T resources															2		2
Assisted T pedagogy															1		1

1
These are 'strengths' as listed by teachers for the overall unit.

2
T=Teacher; S = Student.

4.2B Teacher perceptions of weaknesses[1] of Primary Connections units[2]

Unit/Strengths[3]	WW	Ww	SS	EP	WM	MMat	ASS	CD	OTM	PP	SM	EC	SA	SZ	PA	MM	Total
Unit too long/too much content	2	1		3	1	2		2		2	1		1	1	5	1	22 (29%)
Lessons too long	1					1	3	2		1				1			10 (13%)
Lacked cohesiveness/ concept development			1			1		1				1	1				5 (7%)
Concepts too complex/ abstract			1	2							1						4 (5%)
Did not capture T interest						1	1				2						4 (5%)
Did not capture S interest																	3
Problematic/low impact on S learning				1		2											3
Excessive T talk/ explanation; needs more inquiry						3											3
Inability of Ss to appreciate role of mental/physical models						3											3
Equipment/materials not easily accessible							1									2	3
Stronger literacy links needed	1							1						1			3
Concepts too simple											1	1					2
Lacked S relevance/links to world						1										1	2
Did not appreciate focus on one key idea/wider content scope needed investigation/fair testing/ observations impact			1	1													2
Too advanced for K/Prep	2																

1
These are 'weaknesses' as listed by teachers for the overall unit.

2
Perceptions indicated by only one teacher: More variety needed in teaching strategies from unit to unit (MM); more assistance with 5E model needed (PP); inappropriate activities (invertebrates) (SZ); more ICT needed (SZ); not consistent with State syllabus (MMat); lesson steps too detailed (ASS); difficulty of night observations (EP); did not meet S expectations (Space unit) (EP); repetitious in places (MM); beyond S skill level (WM).

3
T=Teacher; S = Student.

4.3 Teacher responses to a two-tier test assessing and understanding of the learning cycle (Odom & Settlage Jr., 1996)

(N=11)[1]

Item	Applies to Phase	Correct Response Frequency	REASON Correct Response Frequency	REASON Incorrect Response Frequency
1	Elaborate	5	5	
2	Elaborate	8	6	A1 C1
3	Explore	3	2	B1
4	Elaborate	7	1	A3 C1 D2
5	Explain	4	3	C1 D1
6	Explore	9	9	
7	Explore	8	8	
8	Elaborate	5	3	A1 C1
9	Explain	5	4	C!
10	Elaborate	9	7	B2
11	Explore	10	5	A4 D1
12	Explore	8	8	B1
13	Elaborate	4	4	

1
Detailed analyses not included due to the small sample size and low response rate. Item information is available in Odom & Settlage Jr. (1996).

4.4 Reported times (minutes) for implementing 5E phase lessons in Primary Connections units

Unit	Engage	Explore	Explain	Elaborate	Evaluate	Total time (hours)
Spinning in space SS S2	85, 120, 135	L2 120 L3 50, 210	30, 120	70, 120	50, 120	7–12 hours
On the move OTM ES1	80, 60, 120, 60, 75, 40	L2 75, 60, 40 L3 70, 60, 90, 60, 45, 40 L5 (Optional) 70, 75, 60, 60, 60, 40	40, 30, 40, 45, 30, 45	40, 30, 60, 90, 90	65, 30, 60, 45	5–8 hours (excluding L5)
Electric circuits EC S3	190	L2 120 L3 120, 60 L4 120			7.5 hours	8 hours (*Engage* + *Explore* only)
Marvellous micro-organisms MM S3	180, 180, 180, 75, 60, 270, 135	L2 40, 50 90, 60, 30 (excluding wait time) L3 50, 80, 60 L4 20, 60 (excluding wait time)	40, 50	L6 90, 120 L7 135, 8 hours		7–13 hours (excluding wait time + *Evaluate*)
Material matters S1	60, 75, 45, 75,	L2 60, 45, 60, 75 L3 50, 45, 45 L3 60, 90, 60, 60, 180	120, 45, 30, 90	L6 N/A L77 65	60	6–10 hours

5.1 Frequency of teacher responses indicating if the 'purposes' of the 5E phases were addressed (specific units)

The tables in this section are presented in the following order:

Stage	Trial Unit Title (Final Title)
Strand	Natural and Processed Materials
ES1	*What's it made of?* (*What's it made of?*)
S1	*Material matters* (*Spot the difference*)
S2	*All sorts of stuff* (*Material world*)
S3	*Change detectives* (*Change detectives*)
Strand	Life and Living
ES1	*Staying alive* (*Staying alive*)
S1	*Schoolyard zoo* (*Schoolyard safari*)
S2	*Plants in action* (*Plants in action*)
S3	*Marvellous micro-organisms* (*Marvellous micro-organisms*)
Strand	Energy and Change
ES1	*On the move* (*On the move*)
S1	*Push-pull* (*Push-pull*)
S2	*Smooth moves* (*Smooth moves*)
S3	*Electric circuits* (*It's electrifying*)
Strand	Earth and Beyond
ES1	*Weather in my world* (*Weather in my world*)
S1	*Water works* (*Water works*)
S2	*Spinning in space* (*Spinning in space*)
S3	*Earth's place in space* (*Earth's place in space*)

INTERPRETATION OF THE TABLE

1. The frequencies are 'best estimates' from a reiterated interpretation of the responses, but inferences are sometimes drawn from limited expressions of teacher feedback. Where frequencies are in parentheses, evidence for the 'purpose' is more implied than direct, although the parentheses may also indicate that feedback on whether the purpose has been addressed is problematic. Frequencies are still included as it is more probable that the purpose was addressed, and sometimes footnotes are inserted to clarify their meaning. Where '>' is inserted it indicates the number cited could be higher. The frequencies are still indicative of the major impressions that the responses provide.
2. The 'N=' value associated with each phase is the maximum number of teacher responses that were made for any one, (or combination of), lesson(s) in that phase.
3. The frequencies cited for a 'purpose' within a phase refer to the number of different teachers who addressed the stated purpose in at least one of the lessons associated with a phase.

Appendix 5.1, table 5.1: *WHAT'S IT MADE OF?* (ES1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed*

N = 12 (maximum)

Phase	Purpose	Addressed	Addressed with difficulty/ (not addressed)
Engage (N=12)	Create interest and stimulate curiosity	4	1
	Set learning within a meaningful context	1 (+1)	1
	Raise questions for inquiry	-	-
	Reveal students' ideas and beliefs, compare students' ideas	1	1
Explore (N=9)	Provide experience of the phenomenon or concept	9	-
	Explore and inquire into students' questions and test their ideas	3	-1
	Investigate and solve problems	(2)	-
Explain (N=6)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	-
	Compare explanations generated by different students/groups	0	-
	Consider current scientific explanations	0	-
Elaborate (N=12)	Use and apply concepts and explanations in new contexts to test their general applicability	3 (+2)	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	4	-
Evaluate (N=5)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	2	-
	Provide evidence for changes to students' understanding, beliefs and skills	0	-

* On the basis of teachers' comments it is problematic as to whether some teachers addressed these purposes; hence responses have been left as '-'.

Appendix 5.1, table 5.2: *MATERIAL MATTERS* (S1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 14 (maximum)

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=12)	Create interest and stimulate curiosity	9	4
	Set learning within a meaningful context	0	-
	Raise questions for inquiry	0	-
	Reveal students' ideas and beliefs, compare students' ideas	3 (+1)[1]	1
Explore (N=7)	Provide experience of the phenomenon or concept	7	-
	Explore and inquire into students' questions and test their ideas	2[2]	6[2]
	Investigate and solve problems	3[2]	-
Explain (N=8)[3]	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	5	4 (1)
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	-
	Compare explanations generated by different students/groups	1	-
	Consider current scientific explanations	5	4
Elaborate (N=8)	Use and apply concepts and explanations in new contexts to test their general applicability	1 (+3)	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	0	-
Evaluate (N=5)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	1 (+2)[4]	1
	Provide evidence for changes to students' understanding, beliefs and skills	0	-

1
+1 here refers to a later lesson where this was the purpose

2
It is problematic how many teachers addressed these purposes, but the numbers were minimal, compared to some of the other purposes of this phase; *see* Chapter 5.2

3
N=8 is most likely value as *Explain* lesson in trial version (L5) was made another phase in final version.

4
See (2) but also that inquiry skills did not seem to be explicitly mentioned.

Appendix 5.1, table 5.3: *ALL SORTS OF STUFF* (S2)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 18 (maximum)

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=18)	Create interest and stimulate curiosity	10 (+6)[1] (FN1)	4
	Set learning within a meaningful context	2	(1)
	Raise questions for inquiry	-	-
	Reveal students' ideas and beliefs, compare students' ideas	>5 (2+)[1]	2
Explore (N=19)	Provide experience of the phenomenon or concept	19	-
	Explore and inquire into students' questions and test their ideas	>4 (+1) (at least 12)[2]	-[2]
	Investigate and solve problems	>5 (at least 12)[2]	-[2]
Explain (N=12)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon.	7	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	5 (+1)	-
	Compare explanations generated by different students/groups	3	-
	Consider current scientific explanations	5 (+2)[3]	-
Elaborate (N=10)	Use and apply concepts and explanations in new contexts to test their general applicability	2 (+1)[3]	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	4	-
Evaluate (N=8)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	5	2
	Provide evidence for changes to students' understanding, beliefs and skills	3	-

1
In the Engage phase, the '+6' likely refers to additional classes (explained within the teachers' notes); (2+) refers to possibly two responses that implied addressing the purpose, while the + possibly means that more comments implied the purpose was addressed. However, the comments were more problematic. The '5' refer to revealing students' ideas but the teachers may have misunderstood its purpose.

2
>4 and >5 are used here as testing student ideas, and investigation planning may be implied in many comments that referred to fair testing (e.g., a further 9 in lesson 2 in the explore phase: *see* teacher comments); some teachers had difficulties with collecting and preparing materials etc. for fair testing, but these difficulties do not include these purposes were not addressed.

3
The ('+') figures used here indicate less-obvious instances of the particular purposes associated with the Explain and Elaborate phases.

Appendix 5.1, table 5.4: *CHANGE DETECTIVES* (S3)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 10 (maximum)

Phase	Purpose	Addressed	Addressed with difficulty/ (not addressed)
Engage (N=9)	Create interest and stimulate curiosity	9	-
	Set learning within a meaningful context	8	-
	Raise questions for inquiry	(1)	-
	Reveal students' ideas and beliefs, compare students' ideas	5+[1]	-
Explore (N=9)	Provide experience of the phenomenon or concept	9	-
	Explore and inquire into students' questions and test their ideas	>4[2]	3[2]
	Investigate and solve problems	8[2]	2[2]
Explain (N=6) [Elaborate= Explain (N=8)] 3	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	>5 [8]	2 [2]
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	5 [8]	-
	Compare explanations generated by different students/groups	>2 [>6]	-
	Consider current scientific explanations	>2[4] [8]	[2]
Elaborate (N=8)	Use and apply concepts and explanations in new contexts to test their general applicability	1 (=6)[4]	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>6[4]	3
Evaluate (N=4)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	4	1
	Provide evidence for changes to students' understanding, beliefs and skills	2	-

1
It is clear that students' ideas were compared in at least five (of nine) responses and probably more; however, in some instances this may not have been for the purposes expected in the Engage phase (i.e., teachers are encouraged not to 'correct' at this phase).

2
Testing student ideas was more likely than enquiring into students' questions. 'Greater than' (>) is shown since testing students' ideas, and investigating problems more than likely occurred in other teachers' classes. Students clearly investigated what happened in various 'change' phenomena, but whether they were investigating any specific ideas is not clear nor is whether they 'solved problems'.

3
In the trial version there was an interchange between the Explain phase lessons and the Elaborate phase lessons. The values in the square parentheses refer to an Elaborate lesson that became an Explain lesson.

4
The ('>') suggests the number may have been greater. In the elaborate phase, the concept 'applied'/ 'extended' was probably more the notion of a fair test rather than 'change'.

Appendix 5.1, table 5.5: *STAYING ALIVE* (ES1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 9 (maximum)

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=8)	Create interest and stimulate curiosity	>4	1
	Set learning within a meaningful context	5	-
	Raise questions for inquiry	0	-
	Reveal students' ideas and beliefs, compare students' ideas	5[1] (compare)	-
Explore (N=9 max)	Provide experience of the phenomenon or concept	8	1
	Explore and inquire into students' questions and test their ideas	>5[2]	-
	Investigate and solve problems	>4[2]	-
Explain (N=5)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	-
	Compare explanations generated by different students/groups	1 (+2)	-
	Consider current scientific explanations	>2[3]	3 (1)[3]
Elaborate (N=8)	Use and apply concepts and explanations in new contexts to test their general applicability	>5	(1)
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>5[4]	-
Evaluate (N=3)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3[5]	-
	Provide evidence for changes to students' understanding, beliefs and skills	>2	-

1
There were no direct responses suggesting students revealed their ideas about living things, but they did compare their thoughts about pets.

2
Testing student ideas was probably occurring simply by the nature of some of the 'sense' activities but teacher comments really did not make it clear that students were testing *their* ideas; there were not indications that students enquired into their own questions. 'Greater than' (>) is shown as testing student ideas, and investigating problems more than likely occurred in other teachers' classes.

3
The scientific view is implied if the Venn diagram task is completed, but only two teachers referred to it.

4
Most teacher comments focused on the nature of the investigation (and this probably implies that the concept 'needs of living things' was discussed; however, only one teacher made explicit reference to it.

5
Comments suggested a review, not a reflect, focus on living things. The review probably focussed on science understandings.

Appendix 5.1, table 5.6: *SCHOOLYARD ZOO* (S1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 12

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=12)	Create interest and stimulate curiosity	>10	1
	Set learning within a meaningful context	>5[1]	1
	Raise questions for inquiry	0	-
	Reveal students' ideas and beliefs, compare students' ideas	>6 (compare)	-
Explore (N=12 max)	Provide experience of the phenomenon or concept	11	1
	Explore and inquire into students' questions and test their ideas	>5[2]	-
	Investigate and solve problems	>9[2]	-
Explain (N=9)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	8	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	-
	Compare explanations generated by different students/groups	>2	-
	Consider current scientific explanations	>4[3]	-
Elaborate (N=5)	Use and apply concepts and explanations in new contexts to test their general applicability	>2[4]	(1)
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>4	-
Evaluate (N=5)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3 (+2)[5]	-
	Provide evidence for changes to students' understanding, beliefs and skills	>1[5]	-

1
If the school grounds are considered a meaningful context, then 11/12 teachers met this criterion. However, none referred to 'context' in terms of relating the concepts directly to students' interests. The >5 refers to the Resource Sheet 'In my own backyard', which clearly placed the learning in a meaningful context (their home). One teacher did not take the students into school grounds.

2
Testing students' ideas was obvious in a few comments, but observation and recording tended to dominate. 'Greater than' (>) is shown a since testing student ideas, and investigating problems more than likely occurred in other teachers' classes.

3
Comparing ideas was assumed if 'discussion' was mentioned; the scientific view was assumed if science understanding terminology included (e.g., 'how we live'; 'compare and contrast').

4
Here, 'extending' the concept of similarities and differences in living things (e.g., their habitat) was assumed to be an application of a concept.

5
All five comments were general with only one teacher making a specific reference to the occurance of learning. Review (rather than reflect) was the focus as was science understanding.

Appendix 5.1, table 5.7: *PLANTS IN ACTION* (S2)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 12

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=10)	Create interest and stimulate curiosity	>9	-
	Set learning within a meaningful context	>9[1]	1
	Raise questions for inquiry	(3)[2]	-
	Reveal students' ideas and beliefs, compare students' ideas	>7	-
Explore (N=12 max)	Provide experience of the phenomenon or concept	7	5[3]
	Explore and inquire into students' questions and test their ideas	>1[4]	-
	Investigate and solve problems	>1 (+3)[4]	-
Explain (N=8)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	>5	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	-
	Compare explanations generated by different students/groups	>1 (+1)	-
	Consider current scientific explanations	>(4)[5]	-
Elaborate (N=9 max)	Use and apply concepts and explanations in new contexts to test their general applicability	(5)[6]	(1)
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	7[7]	-
Evaluate (N=7)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	6[8]	-
	Provide evidence for changes to students' understanding, beliefs and skills	>3[8]	-

1
Since the Green Buddies task was set in home gardens, it is assumed to be a meaningful context and 9/11 teachers referred positively to this activity. However, none referred directly to 'context' in terms relating the concepts directly to students' interests, except for T1 who linked the ideas to Joseph Banks.

2
No teachers referred to students' questions, but KWHL was mentioned in three responses.

3
Experience of the phenomenon of seeds and their germination was in all responses; however of these 12 responses five teachers encountered difficulties that they overcame.

4
Testing students' ideas was not obvious. Observation and recording tended to dominate. Investigating and solving problems was not the focus of comments; it appeared students watched seeds germinate and recorded changes (rather than seeking an answer to a problem).

5
The scientific view was assumed if representations were mentioned, although conceptual language was not used—hence parentheses.

6
If 'investigation planner' or similar was mentioned it was assumed that a condition for plant growth was explored; hence extension of the concept of plants as living things was the focus rather than the application on a concept (hence parentheses used).

7
This was across four *Elaborate* lessons where teachers referred to a mode.

8
Mixture of review and reflect comments, but mainly science understandings, except for one teacher who also included learning processes.

Appendix 5.1, table 5.8: *MARVELLOUS MICRO-ORGANISMS* (S3)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 18

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=18)	Create interest and stimulate curiosity	>8	-
	Set learning within a meaningful context	>(3)[1]	-
	Raise questions for inquiry	1 (+2)[2]	-
	Reveal students' ideas and beliefs, compare students' ideas	2 (+2)[2]	-
Explore (N=15 max)	Provide experience of the phenomenon or concept	>11	3[3]
	Explore and inquire into students' questions and test their ideas	>7	3[3]
	Investigate and solve problems	>10 (+3)	3[3]
Explain (N=10)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	>6	(2)
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	(2)
	Compare explanations generated by different students/groups	>1 (+5)[4]	(2)
	Consider current scientific explanations	>1 (+7)[4]	(2)
Elaborate (N=16 max)	Use and apply concepts and explanations in new contexts to test their general applicability	1 (+10)[5]	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	7	-
Evaluate (N=4)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3 (+1)[6]	-
	Provide evidence for changes to students' understanding, beliefs and skills	3[6]	-

1
Although 'bread' was the focus, teachers' comments did not directly address this purpose. It may have been assumed that students would implicitly see it as a meaningful context. Three statements alluded to relating tasks to everyday contexts, hence parentheses.

2
Some teachers did not complete or had difficulty with some of the *Explore* lessons with yeast and bread-making either because the activities did not work or they were unable to obtain equipment.

3
Experience of the phenomena with yeast and breads caused considerable difficulties for some teachers.

4
No teachers referred specifically to micro-organisms, and only one referred to related language; others implied *Explain* activities were successful; there were no clear comments about students sharing their explanations.

5
Only one teacher suggested that there was an application of learning about micro-organisms in a new context, but at least 10 referred to fair testing of various conditions for growth of micro-organisms (which can be understood as using fair testing in a new context and possibly/probably applying a knowledge of micro-organisms to thinking about their growth).

6
This includes two teacher comments about the journal (not included in the *Evaluate* phase feedback).

Appendix 5.1, table 5.9: *ON THE MOVE* (ES1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 10

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=9)	Create interest and stimulate curiosity	5	2
	Set learning within a meaningful context	2	-
	Raise questions for inquiry	1	-
	Reveal students' ideas and beliefs, compare students' ideas	4+[1]	1 or 2[1]
Explore (N=9 max)	Provide experience of the phenomenon or concept	9	-
	Explore and inquire into students' questions and test their ideas.	>3[2]	1[2]
	Investigate and solve problems	5[2]	1[2]
Explain (N=7)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	1 (+1)	-
	Compare explanations generated by different students/groups	3	-
	Consider current scientific explanations	2[3]	
Elaborate (N=8)	Use and apply concepts and explanations in new contexts to test their general applicability	6 (+2)	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	7	-
Evaluate (N=6)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	4[4]	-
	Provide evidence for changes to students' understanding, beliefs and skills	2	-

1
It is probable that students' ideas were revealed in more responses; however in one or two instances it is unclear as to whether the teacher provided definitions or examples of things that move rather than simply eliciting students' conceptions.

2
Testing students' ideas was more likely than enquiring into students' questions. 'Greater than' (>) is shown since testing students' ideas, and investigating problems more than likely occurred in other teachers' classes. Students clearly investigated what happened with various 'movement' phenomena, but only in a couple of cases was it clear students were investigating any specific ideas and 'solving problems'.

3
It was rare for teachers to actually refer to the conceptual area (here 'movement').

4
Mainly review, not reflect, comments about movement.

Appendix 5.1, table 5.10: *PUSH-PULL* (S1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 8

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=8)	Create interest and stimulate curiosity	2	8[1]
	Set learning within a meaningful context	1	7[1]
	Raise questions for inquiry	0	8[1]
	Reveal students' ideas and beliefs, compare students' ideas	1	8[1]
Explore (N=7 max)	Provide experience of the phenomenon or concept	7[2]	-
	Explore and inquire into students' questions and test their ideas	4[3]	1[3]
	Investigate and solve problems	4[3]	-
Explain (N=7)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	5[4]	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	0	-
	Compare explanations generated by different students/groups	0	-
	Consider current scientific explanations	4 (+2) [5]	2
Elaborate (N=6)	Use and apply concepts and explanations in new contexts to test their general applicability	1 (+5)	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>1[6]	3
Evaluate (N=7)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3[7]	-
	Provide evidence for changes to students' understanding, beliefs and skills	1	-

1
Small frequencies occur because many teachers are preoccupied with time, preparation and other issues (e.g., lack of student skills).

2
All 7 students experience the phenomenon, but there were minor difficulties with 2 teachers.

3
Testing students' ideas was more likely than enquiring into students' questions. 'Greater than' (>) is shown since testing students' ideas, and investigating problems more than likely occurred in other teachers' classes. Students clearly investigated what happened in various *push-pull* phenomena, and in some lessons it was clear that students were investigating specific ideas and 'solving problems' (e.g., getting objects to float).

4
Conceptual tools were, however, limited to mainly teacher explanation.

5
Two teachers implied scientific views introduced.

6
Five teachers referred to various modes re fair testing, but only one mentioned 'forces'.

7
Mainly review, not reflect, comments about understanding *push-pull* ideas.

Appendix 5.1, table 5.11: *SMOOTH MOVES* (S2)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 9

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=9)	Create interest and stimulate curiosity	8	3 (+4) [1]
	Set learning within a meaningful context	0	-
	Raise questions for inquiry	1	
	Reveal students' ideas and beliefs, compare students' ideas	4 (+1)	1
Explore (N=9 max)	Provide experience of the phenomenon or concept	7	1
	Explore and inquire into students' questions and test their ideas	>2 [2]	-
	Investigate and solve problems	>5 [2]	-
Explain (N=7)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	6	4 (1)
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	6 [3]	-
	Compare explanations generated by different students/groups	>1	-
	Consider current scientific explanations	>4 [4]	3 (1) [4]
Elaborate (N=8)	Use and apply concepts and explanations in new contexts to test their general applicability	1 (+1) [4]	(2) [4]
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>1 (+4) [5]	6 [4]
Evaluate (N=6)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	>3 [6]	-
	Provide evidence for changes to students' understanding, beliefs and skills	1 (+1)	-

1
The +4 is because four teachers indicated the unit overall did not engage students; however, in this phase three teachers gave both positive and negative responses.

2
Testing students' ideas was more likely than enquiring into students' questions. It is difficult to discern if the 'questions' were the students' or from the unit. 'Greater than' (>) is shown since testing student ideas, and investigating problems more than likely occurred in other teachers' classes. Students clearly investigated what happened in various force phenomena, and in some lessons it was clear that students were investigating specific ideas and 'solving problems' (e.g., friction on different surfaces).

3
Justifying claims was not as explicit, but could be implied in a couple of instances although sometimes with, difficulty because some teachers considered the concepts were complex.

4
Most teacher comments focused on use of, or difficulties with, carrying out a fair test.

5
Fair testing dominated comments and only T3 referred to discussions about forces. Four teachers did refer to graphing (mathematical mode) and one teacher recording but it is not clear whether this was an extension of ideas about forces.

6
Mainly review, not reflect, comments about science understandings about forces.

Appendix 5.1, table 5.12: *ELECTRIC CIRCUITS* (S3)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 16

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=16)	Create interest and stimulate curiosity	13	-
	Set learning within a meaningful context	>2	-
	Raise questions for inquiry	3	1
	Reveal students' ideas and beliefs, compare students' ideas	5+[1]	(2) [1]
Explore (N=16 max)	Provide experience of the phenomenon or concept	14	-
	Explore and inquire into students' questions and test their ideas	>7[2]	1[2]
	Investigate and solve problems	>7[2]	-
Explain (N=14)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	10	2
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	5 (+2)	-
	Compare explanations generated by different students/groups	0	-
	Consider current scientific explanations	>8	2
Elaborate (N=11 max)	Use and apply concepts and explanations in new contexts to test their general applicability	5	5[3]
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	8	-
Evaluate (N=9)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	>8	-
	Provide evidence for changes to students' understanding, beliefs and skills	>4	-

1
It is probable that students' ideas were revealed in more responses; however in one or two instances it is unclear as to whether the teacher provided definitions or examples of things that move.

2
Testing student ideas was more likely than enquiring into students' questions. 'Greater than' (>) is shown since testing student ideas, and investigating problems more than likely occurred in other teachers' classes: e.g., where 'representations' was mentioned but not necessarily testing. Students clearly investigated what happened in various 'circuit' phenomena.

3
Three of the five teachers here also applied the concept in a new situation but referred to equipment issues.

Appendix 5.1, table 5.13: *WEATHER IN MY WORLD* (ES1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 12

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=12)	Create interest and stimulate curiosity	>4[1]	7
	Set learning within a meaningful context	>2 (+1)	-
	Raise questions for inquiry	(1)	1 (1)
	Reveal students' ideas and beliefs, compare students' ideas	>1 (+1)[2]	-
Explore (N=11 max)	Provide experience of the phenomenon or concept	7	7[3]
	Explore and inquire into students' questions and test their ideas	>0[3]	-
	Investigate and solve problems	>3	6[3]
Explain (N=8)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	2	4 (2)[4]
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	0	-[4]
	Compare explanations generated by different students/groups	(1)	-[4]
	Consider current scientific explanations	>0	-[4]
Elaborate (N=7)[5]	Use and apply concepts and explanations in new contexts to test their general applicability	1 (+1)	3 (+2)
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	1	-
Evaluate (N=3)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3	-
	Provide evidence for changes to students' understanding, beliefs and skills	0	-

1
There were two *Engage* lessons in the trial unit. The second became an *Explore* lesson in the final version. In the second *Engage* lesson seven teachers indicated students were interested in the lesson; two others referred to a meaningful context.

2
Discussion about the 'letter' (to the class) probably occurred, but only this number of teachers actually referred to students' ideas or possible questions.

3
Several teachers either had difficulty with the *Explore* lessons and/or omitted parts (or all). No comments suggested that students were testing their own ideas or answering their own questions.

4
Only two teachers reported positive responses to the *Explain* phase with four expressing difficulties and two not completing the lesson. Most of the 'purposes' were not implied.

5
The Explore lesson in 'making a wind meter' became an *Elaborate* lesson titled 'Investigating the wind'. This made it difficult to ascertain estimates of 'purpose' frequencies. The numbers in the table refer to the *Elaborate* lessons in the trial unit. (No data have been entered for making a wind meter lesson-most teachers indicated it was a 'good' lesson, with others referring to discussion (T4) and recording (T17). Others had difficulties (T5) or did not complete (T7). There were three lessons in the *Elaborate* phase. Two teachers commented positively, but did not allude to the two purposes; the other five had difficulties or did not complete.

Appendix 5.1, table 5.14: *WATER WORKS* (S1)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 16

Phase	Purpose	Addressed	Addressed with difficulty/(not addressed)
Engage (N=13)	Create interest and stimulate curiosity	>8	-
	Set learning within a meaningful context	>2	-
	Raise questions for inquiry	0	-
	Reveal students' ideas and beliefs, compare students' ideas	>5	-
Explore (N=16 max)	Provide experience of the phenomenon or concept	>15	-
	Explore and inquire into students' questions and test their ideas	>7	-
	Investigate and solve problems	>8	-
Explain[1] (N=10)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	>6	-
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	>2	
	Compare explanations generated by different students/groups	>1 (2)	-
	Consider current scientific explanations	>3	-
Elaborate (N=11 max)[3]	Use and apply concepts and explanations in new contexts to test their general applicability	>4 (4)[2]	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	11	(1)
Evaluate (N=11)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	6	(2)
	Provide evidence for changes to students' understanding, beliefs and skills	1	-

1
'My Water Story' was an *Explore* lesson in the trial but an *Explain* phase in the final version. Here it was treated as in the Explain phase.

2
Graphing could imply students applying ideas about water usage in the home, hence parentheses.

3
This lesson was an Explain lesson in the trail version; here it is analysed as an elaborate lesson, together with 'Water in other places' which became 'Community water use'.

Appendix 5.1, table 5.15: *SPINNING IN SPACE* (S2)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 19

Phase	Purpose	Addressed	Addressed with difficulty/ not addressed
Engage (N=16)	Create interest and stimulate curiosity	4 (+2)	4
	Set learning within a meaningful context	1	-
	Raise questions for inquiry	2	1
	Reveal students' ideas and beliefs, compare students' ideas	7 (+6) [1]	7
Explore (N=19 max)	Provide experience of the phenomenon or concept	18	1
	Explore and inquire into students' questions and test their ideas	2 (+2)	-
	Investigate and solve problems	4	-
Explain (N=14)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	6	2
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	8	2
	Compare explanations generated by different students/groups	-	(1)
	Consider current scientific explanations	3 (+2)	-
Elaborate (N=14)	Use and apply concepts and explanations in new contexts to test their general applicability	3 (+2)	1
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	9	1
Evaluate (N=6)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	4	-
	Provide evidence for changes to students' understanding, beliefs and skills	3 (+2)	-

1
This refers to six teachers still identifying students' existing ideas, but having difficulties with their students responding to one or more of the elicitation tools.

Appendix 5.1, table 5.16: *EARTH'S PLACE IN SPACE* (S3)

Frequency of teacher responses suggesting if the purposes of the 5E phases were addressed

N = 15

Phase	Purpose	Addressed	Addressed with difficulty/not addressed
Engage (N=14)	Create interest and stimulate curiosity	10	5
	Set learning within a meaningful context	1	1
	Raise questions for inquiry	(6)	-
	Reveal students' ideas and beliefs, compare students' ideas	6 (>3)	1
Explore (N=13)	Provide experience of the phenomenon or concept	9[1]	10[1]
	Explore and inquire into students' questions and test their ideas	2	>8
	Investigate and solve problems	2	>8[2]
Explain (N=11)	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	9	2
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	6	1
	Compare explanations generated by different students/groups	(4)	-
	Consider current scientific explanations	3	-
Elaborate (N= 14)	Use and apply concepts and explanations in new contexts to test their general applicability	3 (1)	-
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	6	-
Evaluate (N=13)	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3	7
	Provide evidence for changes to students' understanding, beliefs and skills	1	7

1
See chapter 5.2 for commentary relating to these figures.

2
This refers to the number of teachers who had difficulty with Resource Sheet 4 and hence it is assumed that there would be difficulties in fulfilling these *Explore* purposes.

5.2 Frequency of teacher responses indicating if the 'purposes' of the 5E phases were addressed (summary)

Each of the four summary tables in this section refers to four units across four stages and within a science content strand.

INTERPRETATION OF THESE TABLES

1 The titles listed here are used in the trial Primary Connections units: *see* Table 3.1 for titles of published units.

2 These summary tables have been derived from the more detailed tables for each unit: *see* Appendix 5.1.

3 The frequencies are 'best estimates' from a reiterated interpretation of the responses, but inferences are sometimes drawn from limited expressions within a teacher's feedback. Where frequencies are in parentheses, evidence for the 'purpose' is more implied than direct: occasionally, there was a strong impression that several more statements implied that the purpose was addressed, and a range is provided in parentheses to indicate this interpretation. Where '>' is used it indicates the number cited could be higher as interpretations were more problematic. The frequencies are indicative of the major impressions that the responses provided related to the various 'purposes'.

4 The 'N' value is shown as X/Y. The 'Y' value is the number of teachers who returned annotated units for the stated unit. Usually, this is the actual number, but sometimes it is an approximate number. It needs to be appreciated that not all teachers who provided annotated units included feedback that could be aligned with the content of these tables. The maximum number who provided relevant feedback in any one category on the supplied 'Trial Teachers' Curriculum Resource Feedback' questionnaire (e.g., strengths and weaknesses for lessons in the Explore phase) is shown as the 'X' value. Finer detail is available in the tables for each unit: *see* Appendix 5.1.

Appendix 5.2, table 5.1: ENERGY AND CHANGE

Phase	Purpose	*On the Move* ES1 N=9/10	*Push-Pull* S1 N=8/17	*Smooth Moves* S2 N=9/11	*Electric Circuits* S3 N=16/19
Year trialled		October 05	XX Unknown	Term 1, 08	Term 3, 06
Engage	Create interest and stimulate curiosity	5/9	2/8	8/9	13/16
	Set learning within a meaningful context	2	1	0	>2
	Raise questions for inquiry	1	0	1	3
	Reveal students' ideas and beliefs, compare students' ideas	>4	1	>4 (+1)	>5
Explore	Provide experience of the phenomenon or concept	9/9	7/7	7/9	14/16
	Explore and inquire into students'questions and test their ideas	>3	4	>3	>7
	Investigate and solve problems	5	4	>5	>7
Explain	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4/7	5/7	6/7	10/14
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	1 (+1)	0	6	5 (+2)
	Compare explanations generated by different students/groups	3	0	>1	0
	Consider current scientific explanations	2	4 (+2)	>4	>8
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	6 (+2)/8	1 (+5)/6	1 (+1)/8	5/11
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	7	>1	>1 (+4)	8
Evaluate	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	4/6	3/7	>3/6	>8/9
	Provide evidence for changes to students' understanding, beliefs and skills	2	1	1 (+1)	>4

Appendix 5.2, table 5.2: NATURAL AND PROCESSED MATERIALS

Phase	Purpose	ES1 *What's it made of?* (N= 12/12)	S1 *Material matters* (N=12/14)	S2 *All sorts of stuff* (N=18/24)	S3 *Change detectives* (N=9/10)
Year trialled		**Term 1, 07**	**Term 3, 05**	**Term 3, 06**	**Term 1, 08**
Engage	Create interest and stimulate curiosity	4/12	9/12	10 (+6) /18	9/9
	Set learning within a meaningful context	1 (+1)	0	2	8
	Raise questions for inquiry	0	0	0	1
	Reveal students' ideas and beliefs, compare students' ideas	1	3 (+1)	>5 (2)	5+
Explore	Provide experience of the phenomenon or concept	9/9	7/7	19/19	9/9
	Explore and inquire into students' questions and test their ideas	3	2	>4 (+1-8)	>4
	Investigate and solve problems	(2)	3	>5 (+1-8)	8
Explain	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4/6	5/8	7/12	>5 (+3)/6
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	4	5 (+1)	5 (+3)
	Compare explanations generated by different students/groups	0	1	3	>2 (+>6)
	Consider current scientific explanations	0	5	5 (+2)	>2
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	3 (+2)/12	1 (+3)/8	2 (+1)/10	2 (+4)/8
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	4	1(+1)	4	>6
Evaluate	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	2/5	1 (+2)/5	5/8	4/4
	Provide evidence for changes to students' understanding, beliefs and skills	0	0	3	2

Appendix 5.2, Table 5.3: LIFE AND LIVING

Phase	Purpose	ES1 *Staying alive* (N=9/9)	S1 *Schoolyard zoo* (N=12/15)	S2 *Plants in action* (N=12/19)	S3 *Marvellous micro-organisms* (N=18/25)
Year trialled		**Term 4, 07**	**Term 2, 07**	**June, 06**	**Nov, 06**
Engage	Create interest and stimulate curiosity	>4/8	>10/12	>9/10	>8/18
	Set learning within a meaningful context	5	>5	>9	>3)
	Raise questions for inquiry	0	0	(3)	1 (+2)
	Reveal students' ideas and beliefs, compare students' ideas	5 (compare)	>6 (compare)	>7	2 (+2)
Explore	Provide experience of the phenomenon or concept	8/9	11/12	7/12	>11/15
	Explore and inquire into students' questions and test their ideas	>5	>5	>1	>7
	Investigate and solve problems	>4	>9	>1 (+3)	>10 (+3)
Explain	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	4/5	8/9	>5/8	>6/10
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	4	4	1 (+2)	4
	Compare explanations generated by different students/groups	2 (+1)	>2	>1 (+1)	>1 (+1)
	Consider current scientific explanations	>2	>4	>4)	>1 (+5)
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	>5/8	>2/5	(5)/9	1 (+10)/16
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	>5/8	>4	7	7
Evaluate	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3/3	3 (+2)/5	6/7	3 (+1)/4
	Provide evidence for changes to students' understanding, beliefs and skills	>2	>1	>3	3

Appendix 5.2, table 5.4: EARTH AND BEYOND

Phase	Purpose	ES1 *Weather in my world* (N=12/21)	S1 Waterworks (N=16/17)	S2 *Spinning in space* (N=19/21)	S3 *Earth's place in space* (N=15/15)
Year trialled		**May, 06**	**Dec, 06**	**Term 3, 05**	**Term 1, 11**
Engage	Create interest and stimulate curiosity	>4/12	>8/13	4 (+2)/16	10/15
	Set learning within a meaningful context	>2 (+1)	>2	1	1
	Raise questions for inquiry	(1)	0	2	(6)
	Reveal students' ideas and beliefs, compare students' ideas	>1 (+1)	>5	7 (+6)	>6 (+3)
Explore	Provide experience of the phenomenon or concept	7/11	>15/16	18/18	9/12
	Explore and inquire into students' questions and test their ideas	>0	>7	2 (+2)	2
	Investigate and solve problems	>3	>8	4	2
Explain	Introduce conceptual tools that can be used to interpret the evidence and construct explanations of the phenomenon	2/8	>6/10	6/15	9/12
	Construct multi-modal explanations and justify claims in terms of the evidence gathered	0	>2	8	6
	Compare explanations generated by different students/groups	(1)	>1 (+2)	0	(4)
	Consider current scientific explanations	>0	>3	3 (+2)	3
Elaborate	Use and apply concepts and explanations in new contexts to test their general applicability	>1(+1)/7	>4 (+4)/11	3 (+2)/14	3 (1)/13
	Reconstruct and extend explanations and understanding using and integrating different modes, such as written language, diagrammatic and graphic modes, and mathematics	1	11	9	6
Evaluate	Provide an opportunity for students to review and reflect on their own learning and new understanding and skills	3/3	6/11	4/5	3/11
	Provide evidence for changes to students' understanding, beliefs and skills	0	1	3 (+2)	0

5.3 Conceptual tools identified in Explain phase of the trial units

Conceptual tool (N)	Content strand	Unit (Teachers)	Total number of teachers/ strand
Teacher explanation (TE)/Talking/Class discussion (37)	Earth and beyond	WW ES1 (14); Ww S1 (5); EP S3 (8, 9, 12, 15)[1]	7
	Nat/proc materials	ASS S2 (4, 22); CD S3 (1, 6, 9)	5
	Energy and change	OTM ES1 (1, 7, 10); PP S1 (TE) (10, 1, 3, 4); SM S2 (4, 10, 11 (1, 3)) (TE); EC S3 (1, 2, 12, 17)	16
	Life and living	SA ES1 (5, 7); SZ S1 (1, 3); PA S2 (4, 5, 6); MM S3 (2, 7)	9
Role play/ plays (17)	Earth and beyond	SS S2 (1, 2, 8, 15, 19)	5
	Nat/proc materials		0
	Energy and change	SM S2 (1, 10, 11,(6)); EC[2] S3 (1, 3, 6, 12, 15, 16, 17, 18)	12
	Life & living		0
Writing (unspecified/ journal)/sentence completion/ Explanation text (16)	Earth and beyond	WW ES1 (16); Ww S1 (5); EP[1] S3 (13)	4
	Nat/proc materials	WM ES1 (8)	1
	Energy and change	OTM ES1 (9, 10); PP S1 (1, 2)	4
	Life and living	SZ S1 (5); PA S2 (4, 12, 13); MM S3 (5, 19, 24)	7
3-D visual aids/ manipulatives (10)	Earth and beyond	SS S2 (4, 11); EP (7, 13)	4
	Nat/proc materials	ASS S2 (6)	1
	Energy & change	PP S1 (10)	1
	Life & living	SA ES1 (6, 7, 8,); MM S3 (22)	4
Flow chart/Graphs (9)	Earth and beyond	Ww S1 (6)	1
	Nat/proc materials	ASS S2 (6); CD (1, 3, 5, 6)	5
	Energy and change		0
	Life and living	PA S2 (6); MM S3 (23, 24)	3
Drawing/diagrams (8)	Earth and beyond	Ww S1 (12); SS (5, 21)	3
	Nat/proc materials	MMat S1 (1)	1
	Energy and change	OTM (10); EC S3 (4, 17, 18)	4
	Life and living		0
Pictures ((Ts/Ss) charts/posters) (6)	Earth and beyond		0
	Nat/proc materials	WM ES1 (10, 11); MMat S1(3.4); ASS S2 (10)	5
	Energy and change	OTM (1)	1
	Life & living		0

Storyboards (including pictorial) (5)	Earth and beyond	Ww S1 (10, 12, 15)	3
	Nat/proc materials		0
	Energy and change	SM S2 (4, 7)	2
	Life and living		0
AV aids (5)	Earth and beyond	EP S3 (4, 11)	2
	Nat/proc materials		0
	Energy and change		0
	Life and living	SZ S1 (3, 4, 5)	3
Listening (story/big book) Reading (4)	Earth and beyond	Ww S1 (6)	1
	Nat/proc materials	WM ES1 (5)	1
	Energy and change		0
	Life and living	SZ S1 (3); PA S2 (4)	2
Internet (general) (4)	Earth and beyond	EP S3 (8)	1
	Nat/proc materials	MMat S1 (5); ASS S2 (11)	2
	Energy and change		0
	Life and living	MM S3 (2)	1
PM1 (3)	Earth and beyond		0
	Nat/proc materials	ASS 2 (2,6,18)	3
	Energy and change		0
	Life and living		0
Venn diagram (3)	Earth and beyond		0
	Nat/proc materials		0
	Energy and change		0
	Life and living	SA ES1 (7,8); SZ S1 (14)	3
Simulation (2)	Earth and beyond	Ww S1 (4,15)	2
	Nat/proc materials		0
	Energy and change		0
	Life and living		0
Demonstrations (students) (2)	Earth and beyond	SS S2 (2, 6)	2
	Nat/proc materials		0
	Energy and change		0
	Life and living		0
PowerPoint (2)	Earth and beyond		0
	Nat/proc materials	MMat S1 (8)	1
	Energy and change		
	Life and living	PA S2 (6)	
Computer graphics, animation (1)	Earth and beyond		0
	Nat/proc materials		0
	Energy and change		0
	Life and living	SZ S1 (10)	1

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Guest speaker (with visual aids) (1)	Earth and beyond	SS S2 (10)	1
	Nat/proc materials		0
	Energy and change		0
	Life and living		0
Resource sheets (1)	Earth and beyond	OTM (7)	1
	Nat/proc materials		0
	Energy and change		0
	Life and living		0
Thinking hats (1)	Earth and beyond		0
	Nat/proc materials		0
	Energy and change		0
	Life and living	SZ S1 (14)	1

1
It may be assumed that there was 'discussion' and 'writing' around the resource sheet on Galileo, although it was only explicitly mentioned in a few teacher comments. These latter comments are included in the total.

2
Role-play could be implied in all EC responses.

5.4 Frequency and extracts indicating whether current scientific explanations were considered[1]

Unit (conceptual idea)	Conceptual ideas present	Extracts (T) and/or comments	Conceptual ideas absent Extracts (T) and/or commentary
Electric circuits	8	Typical of Ts 1, 2, 3, 4, 13,17,18, 19 were: '... chn. really enjoyed being electrons/energy packs' (1); '(role-play) a good way to have students visualise circuit' (2); 'lesson really extended students' curiosity and learning of electrical circuit, chemical energy, electrical energy and how it is transformed' (13)	Other teachers (Ts 14, 14,16, 19) indicated how successful the lesson was but did not refer to concepts. The phase was not as effective in some classes (Ts 6, 12): *see* section 5.3
All sorts of stuff (properties and uses of materials)	8	In the adjacent column approaches teachers mentioned biodegradability (6, 20) renewable/non renewable (2); plastics (6, 7, 10, 11, 15, 22)	Teachers referred to discussion (6, 11, 22), research (6, 11), explicit written and related outcomes (2, 4, 6, 11, 22), as well as related vocabulary tasks (5, 21)
Material matters (solids, liquids and gases)	5 to 7	Direct reference to concepts associated with strategies/activities was confined to: 'Used jelly instead, children thought jelly not a solid' (1), although the adjacent comments strongly imply the scientific view was considered	Posters and charts implied that the scientific explanation was considered, especially the various feedback comments mentioning the need for 'factual text' to describe solids, liquids and gases (5, 8, 11, 12), as well as the reference to assessment (11, 12)

1
The '*Explain*' phase lesson analysed in CD was an *Elaborate* phase lesson in the trial version. WW and WM did not include comments relevant to this table.

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Change detectives (physical and chemical change)	5	'Used the cards as they were. The chn did not clue into the significance of the words.... It took several goes to get the physical and chemical changes right. They had other ways to group them. We used the 5 why strategy .... We put definitions of physical and chemical change on the information wall' (1); 'Venn diagram worked well. Different groups each had different categories in classifying changes' (3); Revising PowerPoint of changes...demonstrating classification on smart board worked well (5); There was still some confusion as to what to categorise each card. Once we regrouped after the team exercise we were able to discuss the reason for each change placement. This helped classify' (6); '... I also believe that whole sorting out process which the Changes card sort and their discussion allowed for placement of what the students had been learning into organised understandings. This activity was beneficial because organised their own concepts [students] and gave them the time to do it' (9); '... worked fairly well but we did argue a great deal about the differences between the changes and the fact that some can have both' (10)	Two teachers clearly implied classification of changes in: 'Doing it on Interactive white board was brilliant .... Great way to revise everything done thus far .... Used pictures from web rather than words for the Venn diagram' (8); 'As... had covered Venn diagrams twice in Maths as a lead up, this task was fairly forward. Some still need some assistance' (6)
Smooth moves (forces—direction and degree)	4	'I need to do more work on the transfer of energy' (1); 'This storyboard (with descriptive captions and force arrows showing different size and types of forces) was hard for students to understand' (4); 'Many of my kids did not know about energy. This was a very hard concept for my kids to explain. The whole concept of energy transfer and where the energy went was difficult for some to grasp' (T10); 'Students had difficulty understanding what was required of them and what was meant by forces. This took quite a lot of explanation and guidance and prompting to gather required knowledge and understanding... ' (11)	As indicated in the adjacent column, several teachers described difficulties their class had with the scientific view; five in total mentioned learning issues

Push-pull (forces)	4	'... a great lesson. Students loved it. Not confident students understood the pull effect of gravity properly. Not certain how much to explain at this point' (10) 'I still don't understand how to model downward pull with an arrow, as this makes me think downward push—then I don't really know any other way to show it' (1); 'Representation of arrows needs clarification for teachers. I have now discovered that push and pull arrows are shown differently' (3); and ' Gravity was a hard term for the children to really understand' (4)	No conceptual language in: 'Students a bit worried about the vocabulary and found it a challenge' (2)
Water works (water cycle)	3	'The 'water' cycle' was referred to by three teachers (11,12,17)	
Earth's place in space (movement of Earth and Moon in relation to Sun)	3	'Good to reinforce that Earth is not the centre of the universe and to re-visit earlier work' (T14) 'A more traditional style lesson with note-taking skills and the re-visiting of the Orrery helped to cement learning' (T13); and Lesson 4 provided '(T)ime to answer questions and critically check any misconceptions' (T7)	Nature of science concepts (e.g., role of models in seeking explanations) did appear to be a focus for about ¼ of the teachers
Spinning in space (day and night)	3	'Wrapped a large map around student to demonstrate night and day' (1); 'chn came up with heaps of ways to correctly demonstrate (day and night)' (6); 'Starlab dome was more effective to demonstrate science outcome' (4)	Two teachers (T10, T18) did indicate that the (optional) time zone activity was helpful, from which it could be inferred that day and night was explained
Schoolyard zoo (needs and wants of living things)	2	'Session 2 was used as a viewing exercise, techniques (animation, computer graphics) used to give animals human traits to help us understand how they live' (T10); 'Used six thinking hats to explore how it feels to be different animals, Venn diagrams to identify similarities and differences' (14)	Other instances suggested the scientific view, as in' Chn had no difficulty comparing/ contrasting snails and ants (T2); 'Chn wrote an explanation text explaining differences (between ants and worms) (5)
On the move (Movement)	1	Adapted by T (3 rotations): 1. Discuss and demonstrate how toy card move 2. 'Sam' the skeleton—move Sam's body and copy how he stands 3. How animals move—trace animals from tracers and write 3 words about how animals move (10 *Explain* OTM)	

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Staying alive (needs and wants of living things)	1	'We placed items into Venn diagram and we had lots of discussion about whether mobile phones, magazines, sunglasses were really needed (8 SA)	
Plants alive (growth of plants/living things)	1	'… Living, Not Living, Not Sure a fantastic activity' (also implemented some representation options) (6)	Three teachers referred to summaries/recounts (4,6,12) and one to representations (9)
Marvellous micro-organisms (role, uses and conditions for growth)	1	Recorded a common class list of similarities and differences of yeast and no yeast breads (19)	Teachers did not, refer to conceptual idea: Flow chart was, an effective assessment tool (23); 'Children produced good summaries and adding to flow chart was an excellent part of the lesson' (24) 'Students peer reviewed summaries using a comment sheet with headings: What you did well, Some suggestions' (5); 'Summary was comprehensive, did as class, not groups' (7)

5.5 Frequency of teachers using and integrating different modes to help students reconstruct and extend explanations and understanding in the Elaborate phase

Unit	Teachers	Mode(s) [not exhaustive; see footnotes]	Examples of extracts and/or comments
Weather in my world ES1	2	Kinaesthetic (10); Verbal (8)	Used teddies with different outfits (10); We discussed this (8)
Water works S1	11	Graphing (1, 2, 5, 14, 15); graphing + verbal (4,11); mathematical (7,17, 3); verbal + pictorial (10); written (6); verbal (12, 15)	Sticky note graph … early introduction to graphing (20); Good integration with mats (17; also 7); discussed how we used water at home … presented on chart (10)
Spinning in space S2	9	Linguistic (written +verbal) + table (2); written (3, 7); graphical + pictorial (5); graphical (6, 18, 14); graphical + written (9); mathematical (8)	Recoding … discussing … data chart (2); recording (3); used digital photos for retell…hand drawn graphs and Excel (5); measurement each week (8); recorded direction sunrise sunset… used IT for graph (9)
Earth's place in space S3	6	Kinaesthetic + tabular + mathematics + verbal + written (5); Kinaesthetic + visual (8); tables (10); written language (1); verbal+ visual+ written (10); visual (2)	Fascinated with facts and figures … DVD…much discussion … recording … build models (5); physical working with models … visited sites on internet (8); discussion (9); Discussion generated … loved DVD … used it for note taking; U-tube (2); tables for recording data. Referred to mathematical (4) but too difficult (4,8, 10 and not included)
What's it made of ES1	4	Kinaesthetic + verbal (11); Verbal (3,5) + pictorial (10)	Discussion and talk (T3, T5); we put out items … created lot of discussion (11); took before and after pictures (10)
Material matters S1	1 (+1)	Verbal (2); visual (7)	Great discussion (2); watched video (but in *Engage* lesson) then did *Elaborate* task (7).
All sorts of stuff S2	4	Pictorial + verbal (6); Pictorial + mathematical (2); graphical (4), verbal (9)	Coloured individual photos enhanced students' presentation (6); measure how far water went of a towel … photos (2); … had different results, drew up graph for comparison (4)
Change detectives S3[2]	6	Tabular (grid) (3, 5, 6); graphical (6, 9); written + tabular + graphical (6, 9); linguistic [verbal and written] (8,10)	Grid is a great visual way of setting out variables (3; also 5, 6); analysing and comparing graphs … great discussion (6); … spent a lot of time discussing … table investigation planner for recording … displaying data in a graph was a big issue (9)

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On the move ES1	7	Drawing (8), linguistic [verbal + written] (8); written (9) verbal (1), diagrammatic + kinaesthetic (10); pictorial + graphical+ mathematical (5); kinaesthetic + mathematical (7, 8)	Some wrote, some drew (8); wrote ... in literacy lesson (9); organised tested objects (roll/slide) in hoops (Venn) (10); great discussion (1); photos to show fair test (5); record distance rolled with strips of crepe paper (5; also 7, 8); created graph using A3 paper (5)
Push-pull S1	5	Verbal (2); verbal + diagrams + visual (1); written + diagrams + discussion (5); pictorial (4); writing + visual (4); writing (17)	Labelled diagrams ... fantastic (and) explanations (and) digital photos (1); word wall ... discussion ... good diagrams (5); pictures of pushes and pulls more detailed than earlier (4); integrated into writing activities (17) [Only T4 referred to forces]
Smooth moves S2	6	Graphical (1,5,6,11); recording (4); verbal (3)	Only one teacher referred to forces (3); Probably can be assumed that verbal modes used with graphing but not explicit. All teachers reported fair testing, but seven with various difficulties
Electric circuits S3	8	Written (8); Kinaesthetic (12); Kinaesthetic + verbal (13); Verbal (1,3,15); Tabular (17); written (18)	Role-play (13); Children wrote practical report (8); They came up with paper clip switch (12); Enjoyed sharing their ideas (1); Looked for common aspects among materials (17); constructed puzzle cards (18)
Staying alive ES1	5	Graphical (1, 7); graph + discussion (6, 8); mathematical (4)	Bottles represented graph ... marks on bottles (1); human graph ... discussed (8); measured ... water intake (4)
Schoolyard zoo S1	4	Graphical (1, 3); verbal (15); written (4)	Sticky dot method ... for graph (1); very good language outcomes (15)
Plants in action S2	7	Verbal (4, 7, 9); Verbal + other (10, 6) + pictorial (4, 13)	Read books ... shared knowledge (7) think, pair, share (9); Presented investigation at assembly (10); parent audience (for presentation) (6); amazing job on their drawings (4)
Marvellous micro-organisms S3	7[3]	Written (16, 23); Verbal + written (2); visual + written (24, 23); mathematical (4)	(Students) excellent speakers; Discussion and recording (2); work on an investigation planner (and) digital photos and text (23); (student) display ... recording data (24); maths grid ... to measure mould growth (4)

1
Modes may be verbal, written language, diagrammatic, pictorial, graphic, tabular, and kinaesthetic (embodied), which includes gesture and physical action. Depending upon interpretation, modes could also refer to mathematical and figurative forms (apart from pictorial), such as analogous and metaphorical (Tytler, Prain & Peterson, 2007).

2
The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of *Change detectives* S3. Lesson 6 in the draft version is the basis for the data reported here.

3
Teachers also referred to using 'Gardner's multiple intelligences when brainstorming presentation' (16 MM) and that outcomes were a 'great product for portfolios'

6.1 Evidence of the presence of learner roles which facilitate more effective learning of primary science in the *Spinning in space* unit (following Harlen, 2009)

Spinning in Space S2
Evidence of the presence of learner roles which facilitate more effective learning of primary science (following Harlen, 2009)

Perspective Learner roles	Evidence for learner role 1*	Comment
Personal constructivist		
▪ Learning actively (mentally and physically)	OB	▪ Little doubt that active learning occurred
▪ Discussing own and others' ideas	OB	▪ Nature of the 'discussion' usually unclear
▪ Using ideas to try to understand new events/ phenomena	OC	▪ Using ideas to understand new events may be problematic for some students (and teachers)
▪ Reasoning about evidence	OC/OB	
▪ Modifying ideas in the light of evidence	OC/OB	▪ Ideas changed, but problematic as to whether 'evidence' is a focus in many classrooms
▪ Developing 'bigger' ideas from 'smaller' ones	NO	▪ The development of 'big ideas' may need to be made more explicit in units
Discussion, dialogue and argumentation		
▪ Explaining their own ideas to others with examples where appropriate	OB	▪ Discussion apparent in many responses; dialogue problematic but teachers would not use this term. Argumentation probably not as evident
▪ Using language appropriate for explaining scientific phenomena	OB	
▪ Listening and responding to others' ideas.	UC/OC/OB	▪ Responding to others' ideas problematic

*
Decision and comments were formed after becoming familiar with teacher feedback and SIS searching. Refer to table interpretation on subsequent page for an explanation of codes used.

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Enquiry		
▪ Collecting evidence (first hand and from secondary sources) about the world around	OB	▪ Observation and reporting fairly clearly present; at times other enquiry skills also mentioned
▪ Using enquiry skills (observation, prediction etc.)	OB/OC	▪ Argumentation (relating evidence to claims etc.) mentioned occasionally
▪ Learning actively (mentally an physically)	OB	
▪ Reporting and discussing evidence	OB	
▪ Reasoning with others about how different ideas fit the evidences (argumentation)	OC/OB	
▪ Reflecting on learning processes and outcomes	OB/UC	▪ Learning processes may not have been reflected upon
Formative use of assessment		
▪ Taking responsibility for working towards the goals of particular activities	OC/ UC	
▪ Agreeing on the standards of quality to apply in assessing their work	UC/NO	▪ Teachers did not seem to focus on student roles in relation to formative use of assessment apart from reflecting on mainly knowledge outcomes
▪ Participating in self assessment and identifying their next steps	OC/OB	
▪ Participating in peer assessment	NO	
▪ Reflecting on learning processes and outcomes	OC/UC	▪ Student reflection on learning processes seems to be minimal

Similar tables were prepared for each of the 16 analysed units.

INTERPRETATION OF THESE TABLES

1 The titles are the same as used in the trial Primary Connections units.
2 The 'evidence of the presence of learner roles' was an informed impression based on the 5E analyses (*see* Appendix 5.1 and 5.2) and additional searching of teacher comments for these roles conditions. The inferences are made on the basis of feedback comments made across a range of lessons in various phases.
3 The abbreviations used have the following meaning:
- OB = 'obvious', means that the role is most evident;
- OC = 'occasional', means that the role is evident but not regularly mentioned;
- UC = 'uncertain', means that it was problematic as to whether teacher comments indicated this role was evident;
- NO = means that this role was not evident in any teacher comments;
- OB/OC and OC/OB indicate the judgement lies more towards the first mentioned.

8.1 Frequency of students using language appropriate to scientific phenomena

Unit	Teachers	Science journal/ word wall comments (Positive/ Less Positive/ Omit)	Examples[1] and/or comments
Weather in my world ES1	3 (9, 14, 17)	SJ0 WW 0	'Weather terms taught are becoming part of their every day language' (9); 'Children really learnt the vocab on the data chart and used it: Look, it is overcast. (17); '... most now have a good understanding of all weather words' (14).
Water works S1[2]	Implied	SJ 6, 11, 13, 14P WW 3, 5P 130	Introduced 'water dictionaries' (5 *Explore*); played 'oral language games' (ways people use water) (12); literacy aspects strong (4 *Eng*).
Spinning in space S2	1 (3)	SJ 30 2LP WW 2, 3, 4, 11	Children engaged good metalanguage (3, L3).
Earth's place in space S3[3]	1 (4)	SJ 15 WW 4, 13, 15	I used words collected on the word wall as spelling words for the week to help build on their scientific vocabulary (T4: L1) (and later in the unit) I set the students the task of compiling and setting out their own glossary using some of our posters and factual books.
What's it made of ES1	1 (9)	SJ 1,3,6,9P WW1, 2P 30	Many teachers referred to language development, including the difficulties younger students experienced—limited vocabulary (Ts 1, 2, 5, 8); and at least seven teachers in the explore lesson—*see* section 5.2). In the *Explain* lesson class big books (5), pictures and words (10), and large posters (11) were mentioned. 'Created a science journal entry instead of word wall, children drew pictures and teacher scribes how object feels' (9: *Engage*).
Material matters S1	1 (14)	SJ 3P WW 5, 10P 20	A few teachers (e.g., 9, 12) referred to difficulties students had with expressing their ideas about solids, liquids and gases.' This was a great hands on activity and lead to some excellent language for word wall' (14 L3).

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All sorts of stuff S2	6 (4, 9, 13, 14, 15, 21)	SJ 5, 6P WW 20P	'... with children understanding why different materials are used for a particular purpose, a lot of discussion and vocab. development in each session' (14G); '... I got the group to look at the property words and match up the property with a simplified meaning' (15: *Engage*); 'Students developed very good understanding of technical/scientific language (4: *Explore*); 'Students enjoyed using correct terminology in this lesson' (13; *Explore*); '...students enjoyed using scientific terminology—transparent, translucent and opaque (20 *Explore*); 'The table kept the children interested and was useful for vocab discussion[1] (9: *Engage*); Repetition of vocabulary in this unit was a plus. Students using vocab fluently in later lessons' (21: *Explain*)
Change detectives S3[4]	1 (9)	SJ 1, 10P WW 2, 3, 10P	'All children want to talk about science, the connections they have made and their correct use of the science language is very rewarding' (9G); One teacher used journal in every lesson (2); Some teachers said students unfamiliar with language (e.g., evaporate) (Ts 4, UK).
On the move ES1	2 (4, 9)	SJ 1, 2, 7, 8, 9, 10P WW 3, 4, 7P	Children could give me the language (smooth/rough) ... LS18—starting to get good sentences at this time of year .... Excellent timing as we discussing verbs and endings e.g. walk—walks, walked, walking (4); LS19: do as Literacy writing task—Ss individually record own understanding of how they move ... wrote about rolling bodies in literacy session (9).
Push-pull S1	1 (1)	SJ 2, 4, 5P WW 1, 4P	Students easily and automatically used the Predict, Observe & Explain process. Resource sheet excellent. More vocab added to Word Wall. 1PP L3) .... Children could really feel the upwards push of water ... another great lesson that really engaged the students' interest. Great vocabulary. Great discussion. (1PP L4). Some students initially challenged with push pull words (Ts 2,4 L2; 2 *Explain*).
Smooth moves S2	3 (1, 6, 8)	SJ 2, 5, 6P WW1, 5P	The children ... enjoyed the challenge of moving the ball bearing without touching it. These children did *push-pull* previously so they were using terms such as push, pull and force regularly. (6SM L2); In working on defining a fair 'big and small' push we did..._Some used ... in an attempt to define small and large pushes (8SM L2); The exchanges between students using scientific language particularly during the experiments .... The idea of forces is beginning to gel, particularly seen and unseen. (1SM L3 *Explore*).

Electric circuits S3	2 (1, 3)	SJ 2, 3, 16P 5LP WW 3, 9, 12, 13, 17P	Excellent lessons. Chn were really interested and developed well in vocabulary, information and understanding … RS8); The students were really focused and enjoyed their participation—dialogue/ verbalisation included increasing frequency of technical language (1EC *Explore*); Language in word groups was excellent, promoted a lot of discussion, consolidated understandings well. (3 *Eval*).
Staying alive ES1	2 (4, 6)	SJ 7 (class) 1, 5P WW 0	Tree diagram worked well. (4); Chn included traffic lights and specific items of food rather than generic words. (4 L1 SA); Session 1: Students really enjoyed this activity and it worked well. Lots of good vocab generated by students for senses table; We used marshmallows for class mystery object because of allergies. Chn employed good descriptive language after first group or two had had their turn. (6 SA L2).
Schoolyard zoo S1	3 (5, 9, 15)	SJ 1P WW 2, 9P	Students completed own report on earthworms using the process of key words under headings Classification, Description, Location, Dynamics and Conclusion. (9SS L2); Chn wrote an explanation text explaining differences (5) Watched *A Bugs Life* and chn. wrote explanation text about similarities between real ants and movie ants. (5SZ *Explain*); Chn very familiar with the concept of insects being portrayed as human-like. This session had very good language outcomes. (15)
Plants in action S2	3 (1, 7, 10)	SJ 6, 7,uk P WW 6, 8, 21P	Lesson very successful. Much language and discussion from 'Living, Not Living, Not Sure' activity. (1PA *Explore*); Children enjoyed the scientific words. (10PA *Explain*); Learnt how to make real scientific observations using real scientific language. Daily basis made task more relevant. (7)
Marvellous micro-organisms S3	4 (2, 5, 7, 16)	SJ 2, 4, 5, 7, 14, 18 P WW 3, 4, 7, 18, 18, 21	Word usage of scientific language was increased and improved upon. (2); Used it in Unit 1 and would use it again. This time kids collected their own words in science journal, writing them on imaginative single-celled critters. (5 Word wall (MM general); Strong introduction to fair testing, excellent language displayed during working time (7MM *Explore*); Students loved this one! Very hands-on science, Rich in descriptive language (16MM *Elab*).

1
Unless indicated these extracts represent all the comments made by teachers relevant to this attribute.

2
The explain lesson in the trial version (L6) became an elaborate lesson in the final version. It is L6 (Investigating water use at home) and L7 (Water in other places) that is reported here.

3
Moon and star observations were in the EP unit, but teacher comments did not address these except that some said they had difficulty getting students to complete this home task. Some classes did 'observe' computer simulations but these are not recorded in the table. Most teachers reported that students made orreries (albeit several with equipment issues, but very few made mention of how they could have been used to 'test' student ideas about celestial movements.

4
The *Elaborate* lesson (L5) in the draft became the *Explain* lesson in the final version of *Change detectives* S3. Lesson 6 in the draft version is the basis for the data reported her