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Science that Matters: Exploring Science Learning and Teaching in Primary Schools

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Abstract: To help support primary school students to better understand why science matters, teachers must first be supported to teach science in ways that matter. In moving to this point, this paper identifies the dilemmas and tensions primary school teachers face in the teaching of science. The balance is then readdressed through a research-based examination of some of the components underpinning quality science learning and teaching practices. Stories of teachers reshaping their science teaching to enable practical applications of these elements in future practice are shared to illustrate what is possible.

Introduction

Primary science education centers on the work of teachers and the dilemmas involved in deciding what learning matters for their students and how their professional practice will nurture this learning (Lindsay, 2011). As generalists, primary school teachers must determine how, when and where they attend to a range of explicit science curriculum demands while also attempting to balance teaching and learning requirements across all curriculum areas (Smith & Fitzgerald, 2013). These decisions are informed by personal and professional experience, including professional understandings of pedagogy and content knowledge, personal thinking and beliefs about the importance of science and ideas about what science matters for their students (Fitzgerald, 2012). Given the individual nature of teacher expertise and the complexity of professional practice it should come as no surprise that there is evidence of a diverse range of approaches to primary science education in Australian primary schools, at the state, school and classroom level (Tytler, 2007). Diverse approaches to science teaching may be inevitable yet two particularly concerning observations, arise from this diversity:

1. Students experience different classroom representations of the nature of science, i.e., key principles and ideas which provide a description of *science* as a way of knowing and acting, as well as characteristics of *scientific* knowledge. Teachers value and attend differently to these principles and as a consequence students may have limited opportunity to develop a consistent and shared understanding about the inherent values and rigor which define both scientific knowledge, and, the social dimensions of science activity., (Walsh, 2011); and
2. The amount of time devoted to science is inconsistently allocated, e.g. how and when opportunities are made available for students to engage in science learning differs across classrooms (Angus, Olney & Ainley, 2007). This impacts the quality and consistency of student learning experiences (Anderson, 2014)

The interrelated nature of these tensions is important to note. It is because teachers think about science in different ways they therefore work with science in different ways; how they understand the nature of science influences where they find opportunities for science teaching and learning within the context of their classroom (Heap, 2013). These understandings influence where primary teachers find opportunities to position science within existing pedagogical approaches and position learning within the context of student life experience and relevance of world events (Howard, 2011). Teachers, who understand the nature of science as a body of absolute truths, therefore find science difficult to situate within their inquiry approaches to learning. Consequently in these classrooms science may be neglected and/or presented as isolated learning activities (Appleton, 2002). These conditions interrupt and disconnect student learning not only from learning in other areas of the curriculum but also from the context of life experience (Cutter-Mackenzie & Logan, 2013).

In outlining these dilemmas, it must also be acknowledged that primary teachers have much in the way of expertise to contribute to quality science teaching and learning (Smith & Fitzgerald, 2013). Generally in most other areas of the curriculum, they successfully explore pedagogical approaches, which link thinking and skill development across curriculum areas and which situate learning in relevant contexts (Ng, 2013). In general, primary teachers effectively engage students and encourage learning by supporting students to construct new ideas, share new thinking, generate and record data and collect evidence to challenge and sometimes change existing ideas and understandings (Howard, 2011). However, while primary teachers nurture critical thinking and important interpersonal learning behaviours, in the main, they do not recognise these acts as part of learning 'science' (Smith & Fitzgerald, 2013).

In addressing these tensions and dilemmas, this paper highlights what science education in primary schools could look like by sharing stories of classroom practice where teachers are drawing on aspects of quality science learning and teaching to provide their students with learning opportunities that promote meaningful and consistent representations of science. To get to this point, however, it is necessary to explore and grapple with how primary school teachers think about science and science teaching, so that we can start to clearly identify what aspects of science matter and how they might translate into learning experiences.

What is Science?

Understanding why primary school science is enacted in particular ways relies on understanding how primary teachers think about science and how this thinking relates to their science teaching. Recent curriculum developments, such as the Australian Curriculum in Science (Australian Curriculum, Assessment and Reporting Authority, 2015), have explicitly highlighted the need for consistent teaching and learning expectations while also situating science within the overall development of student thinking, understanding and general capabilities. However, the values and intentions of curriculum developers do not always align with the personal practical knowledge of teachers and conversely teachers are not merely the conduits of curriculum. The following exploration and quotes highlight how difficult achieving this alignment is with over forty years of research documenting the need to actively acknowledge and value what teachers bring in terms of the ways they think about science and what this subsequently means in terms of how they think about and enact science learning and teaching.

Connelly (1972) described teachers as 'user developers' of curriculum, not merely implementing the content but translating the external expectations and meanings into meaningful learning within the context of their own classrooms. Andy Hargreaves (1994), in his book *Changing Teachers Changing Times* also recognised the powerful role teachers play when working with curriculum:

Teachers don't merely deliver the curriculum. They develop, define it and reinterpret it too. It is what teachers think, what teachers believe and what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get (p. ix).

The power of teacher thinking in general has been explored by research since the mid-seventies, and has come to acknowledge that decisions about teaching, classroom dynamics and student learning are strongly related to how teachers construct an individual perception of the reality of their classroom (National Institute of Education, 1975). In the eighties, further studies demonstrated that such perceptions evolved from personal experience and consequently, often differed from teacher to teacher and each teaching situation (Elbaz, 1983; Clandinin & Connelly, 1987; Johnston, 1992). Individual perceptions guide teachers through the complex process of planning and implementing curriculum in the classroom and impact on decisions at all levels. Research suggests that the quality of what teachers know and can do has the greatest impact on student learning (Darling-Hammond, 2000; Muijs & Reynolds, 2000; Wellinsky, 2000).

A number of factors influence how teachers think about science and for primary teachers, as generalist teachers, these include the tendency to focus on non-science studies in their own schooling and teacher preparation which in turn appears to diminish their confidence to teach the sciences (Appleton, 1995). Appleton (2003) stated that a recurring theme in much of the literature about primary science education has been the degree of preparedness and apparent reluctance of many teachers to teach science. However, when primary teachers work with science their thinking and decision-making is complex. Appleton (2003) concluded that after exploring how beginning primary teachers' science pedagogical content knowledge (PCK) influenced their science teaching practice, he had a better appreciation of the complexities of teaching and of teacher knowledge and he went further to state:

The teaching profession seems to attract people into primary teaching who fear science rather than those who love it. In much of the literature, many primary school teachers are seen as deficient because of the difficulties they experience with science teaching. I would rather take the perspective that many of these teachers are achieving well within the constraints in which they have to work. They have found that, by drawing on a set of activities that work, they can begin to develop science PCK, however rudimentary, that gets them by in science and provides some science learning for students (p. 21).

A Snap Shot of Teacher Thinking

As eluded to above, it is not surprising that primary teachers respond to the term 'science' in many different ways and this in turn influences what they value as science learning. To further tease out this point, we would like to draw upon a recent experience that the second author had at a curriculum workshop with 23 primary teachers from the same primary school. Four questions were posed to the participating teachers about primary science teaching and learning to gain an insight into their thinking and professional understandings. To scaffold this experience, the teachers completed a post box activity. This activity is designed to develop student ability to retrieve, restructure and extend personal thinking (see Mitchell, 2009). The teachers worked in groups, each were assigned with the collection of responses for specific questions. Teachers read and discussed these responses and bundled them according to similar ideas and comments. The responses were recorded to act as a guide for further staff professional learning. Two of the questions posed were particularly relevant to this paper as they explored how teachers thought about the term ‘science’ and their present approaches to teaching science.

The first question, ‘What is science?’, required the participating teachers to consider and articulate their own personal understandings of the term ‘science’. The responses revealed a range of understandings, such as:

- Everything and everywhere;
- Understanding our world;
- Forming opinions based on evidence;
- The study of how and why things work;
- The interactions between living things; and,
- Inquiring, questioning and investigating the world around us.

The second question required teachers to state how they were presently approaching the planning and teaching of science by completing the following sentence stem, ‘My present approach to science planning and teaching is …’. Again there were a variety of responses, which were categorised and represented by four main groupings.

1. *Limited or no real planning*: Comments from this group included that it was difficult to attend to science in quick and easy ways and there were difficulties experienced in terms of finding science in units and also further complicated by time factors, and specialist programs.
2. *An inquiry approach*: Linking learning across multi-domain (or learning) areas.
3. *Stimulating students by using questions:* To encourage learning and using topics of interest.
4. *Exploring experiments and investigations*.

Although these teacher comments can in no way be construed to be a general representation of primary teacher thinking and practice in relation to science education, they do demonstrate that even within one school, teachers think about science in different ways and attend to science using a range of approaches for planning and teaching. The existence of a range of views and approaches has been reflected in larger surveys and data analyses (Goodrum, Hackling, & Rennie, 2001; Goodrum & Rennie, 2007) and is one of the reasons why science education in general has for many years been seen as problematic. The data from these previous reports also indicated that in primary schools: teaching time is inconsistently allocated in science; teachers use different planning and teaching strategies to enhance learning; and teachers lack a clear and shared understanding of the learning that they value for their students.

Essentially as a result, the teaching of the nature of science is consequently variable in primary classrooms across the country and so therefore students’ science learning experiences are inconsistent (Goodrum et al., 2001). Clearly, there is not a single definitive statement, which captures how primary teachers think about science. Although, some shared emphases have emerged about primary science teaching from this particular workshop experience, which may provide some insights into how teachers decide what has come to matter in primary science education.

What Matters in Primary Science?

The following quotes have been taken from a book published in 1957 entitled *Science in Australian Primary Schools*. They are shared here as they convey an interesting tension that remains in contemporary primary science education around the relevance of knowledge acquisition and the importance of developing the required attitudes and competencies students need to become scientifically literate. Both of these tensions remain in contemporary science learning and sit prominently in the thinking and work of primary teachers as they struggle to find a way to comfortably position the two intentions in their science teaching.

[Science] is first and foremost a class name for all the natural sciences, ranging from the older physical sciences like astronomy and physics to the newer biological sciences such as genetics. Now why are these branches of knowledge all called by the one name science and how do they differ from knowledge which is not science? We can get a clue to this, I think, by contrasting two kinds of knowledge which may conveniently be called public knowledge and private .….Public knowledge then falls into two categories (a) verbal knowledge, and (b) verifiable knowledge. Under (a) the most important fields are mathematics and logic, and under (b) the most important field is science. (Hardie, 1957, p.3-4).

There exists a recognisable elementary school science movement aiming to incorporate comprehensive science courses in the primary school programme. The movement exists not only for the obvious reason that science is becoming more and more important in the surroundings of the individual but also because science can be used in important ways in the emotional education of the individual and because of the social need for a scientifically literate lay population. Foremost among the aims of the elementary school science movement must be put the development of a scientific attitude (Merrilees, 1957, p.30).

The notion of 'public knowledge' or accepted thinking has been a dominant frame of reference for science education suggesting that science learning is really about placing scientists' conceptions in students' minds (Fensham, 1988). Given what we now know about student learning in science, in particular the importance of metacognition, the construction of meaning, the tenacity of alternative conceptions and the nature of science and scientific thinking, this focus on knowledge acquisition seems limited. With this focus it could be easily argued that content knowledge can essentially become an abstract system of scientific knowledge (Fensham, 1988) devoid of meaningful context and the relevance of real situations.

Over recent years, Australian science curriculum has evolved and changed and has attempted to broaden both the nature of science and the processes and skills which are essential components of science learning (e.g. Schools Curriculum and Standards Authority, 2014; Victorian Curriculum and Assessment Authority, 2015). Yet it could be argued that the focus on the acquisition of content knowledge has proved difficult to move in terms of teacher practice in primary science. Primary teachers continue to shape their science teaching around activities that work (Appleton, 2003) producing an approach to primary science that has been characterised by a focus on classroom experiments and the search for 'hands on' activities. While this approach is viewed as effective on one level, there is a tendency to shy away from conceptual learning. In contrast, Fensham (1988) stated that often the role of practical activity is reduced to the enhancement of conceptual learning rather than being a source for learning essential skills and gaining confidence in applying scientific knowledge to solve real world problems, which highlights the need for a more balanced approach.

Curriculum has also explicitly promoted the advantages of inquiry and student centered learning approaches in planning and teaching and this has provided an alternative approach for science teaching, connecting science learning with the thinking, understandings and skills of other curriculum areas.

Inquiry approaches are enjoying a resurgence of popularity in classrooms across Australia. Many contemporary curriculum frameworks such as Tasmania's Essential Learnings locate inquiry as central to effective teaching and learning. … Inquiry learning can happen very effectively within the scope of one key learning area. The best units, however, are those in which students connect learning across the curriculum. There are many reasons why this works so well. Perhaps the most salient is the opportunity this gives students for transfer—central to the development of understanding (Murdoch, 2004, p.1).

These approaches have allowed primary teachers to develop strong pedagogical approaches, which provide students with opportunities to develop a diversity of views, explore a range of contentious issues and situations, develop critical thinking, engage in rich interpersonal learning experiences, and develop meaningful learning. Yet even within schools that have adopted such inquiry approaches, science has not always been successfully integrated or meaningfully linked across curriculum and has often maintained a stand-alone profile as a discrete subject area. In these situations science, unlike other curriculum areas, remains situated within a pedagogy that is teacher directed, relying on contrived learning experiences and disconnected not only from learning in other curriculum areas but also from the context of student life experience.

As previously stated what may underlie these pedagogical tensions is a persisting perception among primary teachers that what matters in science learning is the acquisition of facts and science ideas. This causes tensions for teachers who try to situate science within their inquiry or multi-domain units. These tensions are clearly expressed by teachers as they wrote about their own practice in the following quotes, which have been used to ground this point in the realities of classroom practice:

Five years ago when teaching science to my primary school students, I placed a greater emphasis on teaching science facts and science terminology. I worked on a science topic once a term, or more likely once a year. When the Science unit was over I would take down the classroom scientific display of the children's work at the end of the term and that was it for science for another twelve months! (Verna, 2011, p.67).

Our planning team has stuck to focusing on the key understandings that we wanted our students to get out of a unit of study. In some cases this meant no science whatsoever. In class we had looked at science stories from current happenings, but they were usually unrelated to each other, and often not linked in any way to our multi domain topic (Hose, 2011, p.76).

I really loved those science days when the students moved around different classrooms and experienced science through simple experiments and activities. They were fun days, the students really enjoyed them and the teachers embraced the idea of trying to present many different facets of science, although for me it was still a boxed day of science teaching and learning with very little possibility or intention, to follow up or make connections with what was happening in the classroom let alone the world (Cussen, 2011, p.119).

When teachers' understandings about the purpose of science education are broader than knowledge acquisition then they are more likely to see that science is about ideas, innovations and actions, which are embedded in a range of everyday contexts. These contexts provide rich opportunities for exploring science as a dynamic, collaborative human endeavour arising from curiosity and interest in phenomena identified in everyday life. This thinking is conveyed in the following quote from a primary teacher as they grapple with role as a teacher of science:

The world is ever changing; information is relatively easy to access both at school and at home with a growing range of available multimedia tools. News about local and global events is constant, immediate and often overwhelming. As an educator I need to equip my students for life in this world and I believe that enabling students to become scientifically literate is the key to education in this 21st century. So what does this mean and what does this look like in the classroom? I believe that my teaching must help students to become critical, discerning thinkers who are able to listen, consider, question and interrogate what they read and what they hear. They need to be able to think and adapt to various environments and make decisions about a whole range of changing issues (France, 2011, p. 101).

This conceptual framework moves science from a static, de-personalised, disconnected and largely unattainable body of knowledge to a collection of best explanations and engaging stories embedded in an ever-changing real world social context. Considering science in this way may enable teachers themselves to think differently about what matters in primary science.

Science That Matters: A New Role for Primary Teachers

It is essential that primary science education assists students to develop a more consistent understanding of the nature of science and better equips them to become scientifically literate citizens, which is considered as an important outcome of science education (Roberts, 2007), while also capturing and engaging their interest in learning science. To achieve such learning outcomes requires inevitable changes to the ways in which science teaching is practiced in primary school classrooms. This will require primary teachers to openly acknowledge the dilemmas and tensions they face when teaching science as an opportunity to re-imagine their role as a teacher of science. While there are numerous elements that could be considered in making sense of this new role, three key documents in the Australian context provide rich and detailed descriptions of what characterizes the strategies, attributes and environments of quality science teaching - the national review into *The Status and Quality of Science Teaching and Learning in Australian Schools* (Goodrum et al., 2001), the large-scale *School Innovation in Science* (SIS) project (Tytler, 2003) and the more recently reviewed *National Standards for Highly Accomplished Teachers of Science* (Australian Science Teachers Association and Teaching Australia, 2009 (revised)). In making further sense of these lists of attributes, Hackling and Prain (2005) synthesized these three documents and identified a strong convergence around six characteristics capturing effective science teaching:

1. students experience a curriculum that is relevant to their lives and interests;
2. classroom science is linked with the broader community;
3. students are actively engaged with inquiry, ideas and evidence;
4. students are challenged to develop and extend meaningful conceptual understandings;
5. assessment facilitates learning and focuses on outcomes that contribute to scientific literacy; and
6. information and communication technologies are exploited to enhance learning of science with opportunities to interpret and construct multimodal representations. (Hackling & Prain, 2005, p. 19)

Drawing on this synthesis, this following section will focus particular attention to three areas: the development of a supportive science learning environment (dot point 4), making science relevant (dot point 1), and the role of assessment (dot point 5). These three elements are the focus rather than all six to enable a depth of understanding to the developed about some of practices underpinning understandings of effective science education. Illustrative stories are used to document how teachers are enacting these practices in their classrooms. It is acknowledged that the identified components may help to shed light on what much research and extensive reviews of the literature refer to as quality science learning and teaching, but on their own they cannot bring effective science teaching to life. The stories shared in this paper have been drawn from the practices of four primary school teachers, who participated in a project conducted by the first author of this paper examining effective science teaching in primary school classrooms (Fitzgerald, 2010), and are used to provide insights into what is possible in terms of a science education that matters in primary schools.

Building Supportive Learning Environments

A stimulating classroom environment has a positive impact on student learning (Killen, 2007). Most primary teachers would acknowledge that the aesthetic environment in which students work needs to be engaging and this is evident in the displays and visual arrangements that are characteristic of most primary classrooms. Creating a need to know is also an important condition for learning and most primary teachers work in ways to ensure that teaching attends to this important aspect of learning. Affective engagement is also an important part of science learning, contributing to the development of a more purposeful and positive learning environment. In supporting the development of such an environment, talk has always been highly valued in primary classrooms in terms of literacy and the potential to develop critical thinking and effective communication skills. Talk also has the potential to be an important classroom tool for learning science (Lemke, 1998) as it provides an avenue for the sharing, valuing and nurturing of a diverse range of ideas. Teachers and students can use talk to work through their science ideas and build co-constructed understandings of science phenomena (Mortimer & Scott, 2003). For example, Barnes (2008) highlighted that “the flexibility of speech makes it easy for us to try out new ways of arranging what we know, and easy also to change them if they seem inadequate” (p. 5). It is through this discursive practice, according to Mercer (2000), that students can present their tentative understandings of science and be involved in a process of extending their thinking and learning in science through talking about and connecting with other ideas in a supportive, but challenging environment.

Through working with Deanne (a participant in the project), a Year 6 teacher, it was noted that a characteristic of her practice was the opportunities that she provided her students to talk about their science understandings. Deanne provided students with numerous occasions to discuss science in both the whole-class and small group settings, as well as through one-on-one interactions. However, it was in the small group setting, particularly during hands-on activity work, where her students were most able to talk about and clarify their science ideas. This begins to reveal the balancing act employed by Deanne in supporting students in this process, while encouraging them to take some control of their own learning.

As a precursor to hands-on activity work, Deanne often provided her students with minimal instructions or explanations of the science phenomena they would encounter. This autonomy placed students in a position of uncertainty about how to proceed. Nevertheless, they would quickly engage in discussion as a means of developing an understanding of what was required. Mercer (Mercer, 2008; Mercer, Wegerif, & Dawes, 2004) and his colleagues had developed a body of work, which identified the ways in which students talk to each other in small group settings. These included disputational, cumulative and exploratory forms of discourse. Disputational talk is associated with competitive behaviours and individualised decision-making, which was largely absent from the focus group's discussions. In Deanne's class, the students often engaged in cumulative talk to share and build their understandings. In addition, they frequently used exploratory talk to engage more critically and constructively in making their knowledge and reasoning clearer through discussion.

Deanne's students identified that opportunities for talking about science assisted their learning because it enabled them to voice their ideas, access different perspectives and practice their use of scientific terminology. They also found that engaging in discussion with their peers provided opportunities to hear different points of view, which further strengthened their scientific understandings. Peer group interactions, such as these, typically involved students working in small groups, which provide greater opportunities for all students to engage in discourse, unlike whole-class discussion in which teachers may dominate (Mercer et al., 2004). Mercer and his colleagues (2004) acknowledged that as a part of science education this type of interaction often

Takes place in conjunction with practical investigations or hands-on activities. However, in this case, Deanne's students considered engaging in and listening to discussions with their teacher as being valuable. They identified Deanne's explanations or contributions to whole-class discussion as assisting their learning in science, especially when following after hands-on activity work.

Effective science practice uses talk as a valid way of fleshing out students' existing and developing understandings as well as valuing and nurturing a diversity of ideas. However, students need to be engaged in and supported by their teacher in this process (Alexander, 2008). It is assumed that at the centre of productive and interactive discourse is a classroom culture, which has cultivated a supportive and safe environment around classroom talk where students feel safe to consider different perspectives and share their ideas and where teachers actively withhold judgment in an attempt to nurture and encourage a diversity of ideas.

Making Science Relevant

As Gunstone (1988) stated "learning outcomes depend not only on the learning environment, but also on the knowledge, purposes and motivations the learner brings to the task" (p.77), therefore, learning in science, just as in any other area of the curriculum, must be focused on understanding and making complete sense of ideas and information. As one of the teachers stated earlier in this paper, the learning demands of students living and working in the 21st century and the context and references by which they make sense of ideas and information is constantly changing (France, 2011). The challenge for contemporary science teaching, in particular primary science teaching, is not so much about students acquiring a range of meaningless concepts or honing the skills needed to access information about these concepts, but in building student capacity to develop critical thinking skills that will assist them in making sense of this information. This intention aligns very readily with the learning intentions primary teachers hold for other curriculum areas, however, this task is made very difficult if students feel very little connection between the science they are learning in school and their experiences of science in their daily lives. Primary school teachers, in particular, have an important role to play in better engaging students in science as they have the ability to create primary school science lessons that are exciting for students and encourage curiosity about the world (Harrison, 2007).

The text below highlights the ways in which three primary school teachers focused on making science relevant for their students. The practices of these three teachers revealed that contributing to their science teaching and learning approaches was an awareness of issues related specifically to their students' learning in science. Kate, a Year 4 teacher, supported her students' science learning by incorporating information and communication technologies (ICTs) into her lessons, as she believed that this approach appealed to the ways in which her students preferred to learn. Lisa, a Year 3 and 4 teacher, believed understanding and being able to cater for her students' needs and interests were a central component of her teaching practice in general, rather than being specific to science teaching and learning. Rebecca, a Year 1 and 2 teacher, adopted an integrated approach to science teaching and learning because she believed that it engaged her students in science, as well as assisted her in dealing with a crowded primary school curriculum.

Being aware of student-specific considerations should be acknowledged as a component of science teaching because it enables teachers to design and deliver science learning experiences that are relevant and interesting to their students. These notions of teaching science are not new to primary teachers and are captured within one of the components in Hackling and Prain's (2005) framework, which, as mentioned previously, identifies the characteristics of effective science teaching as derived from a synthesis of the Australian research literature. This particular component identifies that "students experience a curriculum that is relevant to their lives and interests" (p. 19). While teachers readily relate these student-specific considerations to all areas of the curriculum, Kate, Lisa and Rebecca, through knowing their students' needs and interests, were able to develop lessons that were engaging and supported learning in science.

Assessment That Matters

While fostering student interest in science is an important component of the teachers' role, determining if and how students are making sense of information, in particular how they are constructing understandings, is equally important. "Effective science teaching relies on understanding students' pre-existing ideas about science concepts and supporting students to develop more scientific understandings" (Department of Education and Early Childhood Development, 2006). Assessment can be considered as a vital tool for understanding students' ideas and monitoring and evaluating student learning but it is the ways in which teachers use this tool that is crucial (Black & Wiliam, 1998). Teachers should monitor students' developing science understandings by drawing upon and integrating into their practices an array of diagnostic, formative and summative assessment strategies. While this teaching action is common in other areas of primary teaching, such as literacy and mathematics, primary teachers could draw varied assessment approaches for different assessment purposes (e.g. assessment for, of and as learning), to provide their students with opportunities, experiences and feedback that will further enhance their learning. In undergoing conceptual growth, students need to also take responsibility for their learning by being aware of their existing understandings and the further development of these understandings (Hewson, Beeth, & Thorley, 1998). It is this process of students' monitoring their own learning, with the support of their teachers, which assists in bringing about this growth. Feedback on science learning assists students in moving towards scientifically recognised understandings for the phenomena they are experiencing and exploring (Cowie, 2002).

Deanne, a Year 6 teacher from the project, recognised that her role in assisting her students reach their learning potential was to provide them with a high level of challenge in science, which required students to contend with a higher level of conceptual demand. She monitored and supported her students' learning through their involvement in whole discussions, small group activity work and individual tasks, such as their journal entries. Her verbal and written feedback was minimal, but when given, it was often in the form of open-ended questions designed to further probe and query the students' understandings. Deanne's focus was on developing the students' skills in reflecting on their own learning and providing them with autonomy in making sense of the science phenomena they were encountering during hands-on activity work. It was in this forum that students were encouraged to provide each other with feedback on their science ideas and the development of their science understandings.

Lisa, a Year 3 and 4 teacher, used ongoing monitoring, feedback and assessment to support student learning in science in more overt ways than the approach taken by Deanne. Lisa recognised (based on her awareness of her students' learning needs) that she needed to provide her Year 3 and 4 students with a high level of support and scaffolding to achieve conceptual growth over the unit. This was partly addressed through adjusting the unit to focus on three key conceptual areas (the Earth, Sun and Moon; day and night; and shadows), which meant that the learning demand placed on the students was manageable. Lisa monitored the development of the students' science understandings during the unit through the use of formative assessment tasks, such as attending to student responses in whole class discussion, recognising alternative conceptions and responding with appropriate feedback. The feedback that Lisa provided students with during these tasks was designed to encourage students to think more deeply about their science understandings and experiences. Lisa did not often directly explain a concept to the students but instead used a series of questions, or the explanations of other students, to build understanding.

"To achieve high quality learning outcomes … students need to see why, and understand that, their learning matters" (Department of Education and Training, New South Wales, 2003, p. 14). Understandably, many students find it difficult to be enthusiastic about learning if they cannot see the relevance of it. This uncertainty can be addressed, if students are supported through ongoing monitoring of, and feedback, in ways that matter and are meaningful to them. Deanne and Lisa supported their students' learning in science in different ways, which reflected the different learning needs of their students. It is acknowledged that learning with understanding, as well as learning with interest, is more likely to occur when students are provided with opportunities and support to actively construct their own meanings as opposed to passive acquisition and accumulation of knowledge (Fensham, Gunstone, & White, 1994). Innovative and insightful assessment practices have an important role to play in this active construction of science understanding.

Conclusion

In order to ensure meaningful and consistent science learning opportunities at the primary level, primary teachers must be supported to confront their existing ideas about science and science teaching and learning if they are to begin to articulate the problematic nature of the perceptions they use to define their practice. Getting at the ways that teachers think about science and science education is critical if we are to understand what matters in a primary school context and why. With support, primary teachers may begin to think differently not only about their role as science teachers but also the type of learning they value for their students and the role they want to see their students play as active, critical thinkers and learners in science. Documenting stories of primary school teachers drawing on aspects of quality teaching and learning in primary schools is useful in showcasing to others what is possible and encouraging that shift in thinking. Providing alternative ways of thinking about science teaching may enable primary teachers to relinquish their personal feelings of inadequacy, build on their existing pedagogical strengths and provide a consistent science learning experience for all primary students. In this way primary teachers may come to see new possibilities and opportunities for science learning as well as realizing the potential science learning which exists in the experiences that they presently provide for their students.

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