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Facilitating border crossings: A case study of pre-service early childhood teachers' learning about science and science teaching

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Abstract

Using an interpretive case study methodology, and the theoretical concept of border crossings, this research describes the science learning journeys of four pre-service early childhood teachers over a semester science methods course. Based on critical incidents identified by the pre-service teachers during their weekly workshops, vignettes were co-constructed and co-interpreted to describe the nature of each journey, and the pre-service teachers' changing perspectives towards science and science teaching. Common themes across the four learning journeys are identified and described to illustrate the new perspectives these teachers developed along their journey: simplicity, inclusivity, open-endedness, importance of connections, 'disguising' science, and immersion into science. Two assertions are presented that assist teacher educators to construct and manage smoother border crossings for pre-service teachers from early childhood education to science education, framed in terms of representation in science and identify in science.

Introduction

Pre-service early childhood teachers bring a unique and challenging set of characteristics with them when they are learning science, based on their diverse backgrounds and their individual experiences and understandings of previous science study. Most pre-service early childhood teachers have limited science knowledge (Skamp, 1989), narrow perceptions of nature of science (Olson & Appleton, 2006), poor previous science experiences (Appleton, 1991; Garbett, 2003; Mulholland & Wallace, 1994), poor attitudes and beliefs about science and their capacity to be effective teachers of science (Watters & Ginns, 2000; Young & Kellogg, 1993), and limited ideas on how to teach science (Appleton, 2006; Northfield, Gunstone, & Erickson, 1996).

As a means to increase pre-service early childhood teachers' confidence towards science and science teaching, primary science methods courses have incorporated a variety of different approaches. Learning experiences situated within meaningful and authentic contexts have produced positive changes in pre-service teachers' attitude and confidence towards science (Haefner & Zembal-Saul, 2004; Watters & Ginns, 2000). Opportunities to learn science in ways that are consistent with how they are expected to teach, as well as opportunities to learn about instructional strategies and ideas in supportive contexts have contributed towards increased confidence towards science (Appleton, 1995; McLoughlin & Dana, 1999; Mulholland & Wallace, 2000; Ramey-Gassert & Shroyer, 1992; Rice & Roychoudhury, 2003). Opportunities to confront their beliefs about science and their prior experiences as science learners, through reflection and discussion, also have contributed towards pre-service teachers' improved confidence (Abell & Bryan, 1997; Bryan & Abell, 1999).

Along with the characteristics discussed in the first paragraph, pre-service teachers bring strengths to their science teaching. Such strengths include a desire to base curriculum around children's propensity for inquiry; an appreciation of children's fascination with the natural world; a respect for children's intellect; a recognition of children as individuals; and respect for, attention to, and knowledge of children's knowledge, beliefs, and ways of knowing (Howes, 2002). A constructivist approach to science teacher education values these strengths, by attempting to incorporate them into appropriate science learning experiences within the science methods course. This

approach also acknowledges that the teaching and learning beliefs that pre-service teachers hold play a critical role in the interpretation and construction of their knowledge (Bryan & Abell, 1999). Further, these beliefs can be so firmly held that teacher educators must engage and directly challenge the pre-service teacher to bring about effective changes (Bryan & Abell, 1999). Given the dichotomy of incorporating pre-service teachers' strengths with entrenched past experiences, how can a science methods course assist pre-service teachers to redefine their beliefs about science and science teaching?

This paper describes the science learning journey of four pre-service early childhood teachers during a second year science methods course as a means of answering this question. It follows and interprets the science learning experiences of each pre-service teacher. As a means of understanding the changes that occur within the pre-service teachers during the science methods course, the concept of border crossings (Aikenhead, 1996) has been employed. For pre-service teachers, the lived experiences of learning about science and how to teach science can be viewed as a border crossing from early childhood education to that of science education (Fleer, 2006). Further, these experiences are interpreted through the pre-service teachers' changing views of nature of science (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The challenge for the early childhood science teacher educator is to provide smooth and meaningful (Fleer, 2006) border crossings for pre-service teachers through the use of appropriate learning experience. By sharing the science learning experiences of these pre-service teachers, information from this research provides a means to better understand the processes by which these teachers cross the border from early childhood education to science education. Further, information from this research also provides an avenue for the researchers to identify how best to facilitate such border crossings.

This research is framed by the following two research questions:
1. How are pre-service early childhood teachers' views of science challenged by their science learning experiences within a science methods course?
2. How can this information be used to facilitate smoother and more meaningful border crossings for pre-service early childhood teachers from early childhood education to science education?

Border crossings in education

This research pulls on the anthropological framework of border crossings as a means of exploring, describing and comparing the diverse experiences of learners, and providing a means to assist that learning. Giroux (1992) first used the border crossing metaphor to describe the difficulties facing students whose race and culture were different from those of the dominant group. He argued that only when the cultural differences were acknowledged and respected, and therefore taken into account in teaching and learning, was access to education available (Giroux, 1992).

Applying this concept to school science, Aikenhead (1996) suggested that when students learn science they often cross a border from the sub-culture of their peers and family into the sub-culture of school and science. As a means to assisting this border crossing, Aikenhead (2001) proposed that teachers should use a cross-cultural perspective to science education. This perspective should include the acknowledgement

that learning science is a cross-cultural phenomenon for most students, and that students require help to negotiate their border crossings (Aikenhead, 2001).

Mulholland and Wallace (2003) extended this concept to identify and describe the transition from pre-service to in-service teaching for primary science teachers. They suggested that the lived experiences of learning to teach can be viewed as three sub-cultural border crossings: from non-science to science person, from pre-service to in-service teachers, and from teaching other school subjects to teaching school science (Mulholland & Wallace, 2003). While the authors acknowledged that these three sets of sub-cultures were not always distinct, they believed the border crossings metaphor provided "a powerful heuristic for explaining and interpreting the experiences of learning to teach primary science" (p. 883).

Fleer (2006) applied the border crossing concept to early childhood teacher education, highlighting the discrepancy between the theoretical knowledge presented to pre-service teachers at the tertiary level and the pre-service teachers' experiences of working with young children. Fleer (2006) claimed that the lack of research and information on very young children (under 8 years of age) produced a "teaching-learning theory border that these students [pre-service teachers] must negotiate" (p. 115). As the perception of working with very young children is very different to the perception of general science education, Fleer (2006) highlighted the need for early childhood pre-service teachers to cross the border from early childhood pedagogy (theory and practice) to science education pedagogy.

The ease with which border crossings are made depends on the degree of overlap between the participants' existing sub-culture and the sub-culture they are required to enter (Aikenhead, 1996). Difficulties encountered during border crossings are regarded as hazards. Cobern and Aikenhead (1998) classified border crossings as smooth, managed, hazardous, and almost impossible, depending on the degree of difficulty associated with the crossing.

As a means of more effectively facilitating border crossings for pre-service teachers, it is suggested that the science methods course position itself as a vehicle for initiating transition. To achieve this, the approach taken in the current research firstly acknowledges and values the beliefs and experiences that pre-service teachers bring to their science methods course. Secondly, the approach attempts to decrease potential hazards to crossings by increasing the degree of overlap between the pre-service teachers' entering beliefs and experiences and the science learning experiences presented in the science methods course. Allowing pre-service teachers to see and actively make connections with their existing knowledge allows them to take their first tentative steps in crossing over.

Nature of science

Nature of science is concerned with how scientific knowledge is generated and the character of science itself (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). It relates to how science is done and how scientists go about doing their work. No specific definition has been attached to nature of science, highlighting the different interpretations presented in various fields of inquiry (philosophers, historians, sociologists of science or science educators), the multifaceted and complex nature of

science, and the tentative and dynamic character of nature of science (Lederman et al., 2002). However, common aspects of nature of science include that science is tentative (subject to change); empirically based (based on and/or derived from observation of the natural world); subjective (theory-laden); partly the product of human inference, imagination and creativity (involves the invention of explanations); open and accountable; socially and culturally imbedded; there is no one way to do science (no universal 'scientific method'); and laws and theories serve different roles in science (Abd-El-Khalick, Bell, & Lederman, 1998). Further, the use of the term 'nature of science', instead of '*the* nature of science', has been used throughout research to convey the inability of commentators to achieve a single, agreed definition for nature of science (Abd-El-Khalick & Akerson, 2004). These common aspects of nature of science highlight how science is essentially a human activity and a dynamic process (Murcia & Schibeci, 1999).

Views of nature of science are tied to pre-service teachers' beliefs about science teaching and learning. The 'naïve' conceptions of nature of science held by most pre-service teachers leads to a belief in a didactic approach of science instruction, where science is presented as a body of static knowledge (Abell, Martini, & George, 2001). The techniques used during science instruction are also perceived as being static, requiring minimal or no justification (Bartholomew, Osborne, & Ratcliffe, 2004). Pre-service teachers perceive science as a process of discovering what is out there, rather than as a human process of inventing explanations to describe how the world works. Similarly, pre-service teachers see learning as a process of acquiring knowledge through discovery (Abell & Smith, 1994). Such approaches have an emphasis on the product, rather than the processes of science. Further, such approaches to science instruction, which teach about what we know, inhibit any discussion on nature of science, the tentativeness of scientific knowledge, or the social dimensions of science (Bartholomew et al., 2004).

Techniques to improve nature of science in pre-service teachers have centred around the use of scientific inquiry, and explicit instruction through reflection (Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Gess-Newsome, 2002). As a consequence of an inquiry course, Gess-Newsome (2002) found preservice teachers' conceptions of science as primarily a body of knowledge (or product) changed to a more appropriate, blended view of science as a body of knowledge generated through the active application of scientific inquiry (process and product). Akerson, Abd-El-Khalick and Lederman (2000) found that an explicit reflective approach to nature of science instruction, within a science methods course, was effective in producing changes in elementary teachers' views of nature of science. Lederman (1999) considered nature of science such an important instructional objective that it should be a component of every science teacher education instructional unit, lesson and activity.

Methodology

Research Paradigm

A constructivist-interpretative (Cohen, Manion, & Morrison, 2000) research paradigm was adopted in this study, with case study (Stake, 1995) as its organising perspective. Interpretative analysis was used since the aim of this study was to understand the complexities of how pre-service early childhood teachers perceive their science learning

experiences, and how such information could be used to facilitate effective border crossings.

Science Methods Course

This research was conducted over a 10-week semester science methods course during the second year of a four-year Bachelor of Education (Early Childhood Education) degree at an Australian university. The course consisted of weekly 1-hour lectures and 2-hour workshops. The first author was the teacher educator during the science methods course, and the primary researcher. The purpose of the workshops was to make science more accessible to the pre-service teachers, by providing a range of science learning experiences through a hands-on, inquiry approach that focused on developing pedagogical content knowledge. This was achieved through the modelling of early childhood science teaching methods and strategies, guiding pre-service teachers in active and extended inquiry, the development of a positive learning environment, and enhanced reflection. All learning experiences emphasised placing science into an early childhood context, hands-on science activities that could be taken directly into the classroom, discussion of children's views of science, and reinforcing the science investigation process (plan, conduct, process and evaluate) through open investigations.

The workshops were delivered using a social constructivist referent for teaching and learning (Tytler, 2004). Emphasis in the workshops was on participation, where engage, explore and explain from the 5E Model (Australian Academy of Science, 1994) was utilised. All workshops included an initial engagement phase where various techniques to obtain prior knowledge were presented. Pre-service teachers were encouraged to be actively involved in all workshops and investigations, and to ask questions to their peers and the teacher educator. Detailed notes covering both content and pedagogy were handed out at the end of each workshop. Scientific explanations were only offered towards the end of the workshops after sufficient opportunity had been provided for the pre-service teachers to both explore and question themselves and each other. Class reflections were conducted at the end of each workshop, where pre-service teachers were required to reflect on what they had learnt during the workshop, what had happened to assist that learning, and how they could use this knowledge in classroom teaching and learning.

A summary of each week's workshop, along with the topic and science strand, is shown in Table 1. Workshops during Weeks 1 and 2 involved a more formal breakdown and discussion of the characteristics of young children in relation to science, and a discussion of the Science Learning Area from the Curriculum Framework (Curriculum Council, 1998). The remaining workshops (Weeks 3 to 10) involved active investigation. All pre-service teachers had also completed, during the first year of their degree, a science content unit.

Participants

This study focused on the science learning experiences of four pre-service primary teachers training to be early childhood (Kindergarten to Year 3) teachers. These four pre-service teachers volunteered (from two classes of 41 students) to be case studies during Week 2 of the semester, after the research was introduced and described to them during Week 1.

Table 1. Description of the weekly workshops in the science methods course

Week/Topic	Workshop emphasis	Science Focus
1. Introduction and scope	Characteristics of young children from a science perspective	Curriculum Framework
2. Science	Making the science learning areas children friendly, breaking down Investigating	Curriculum Framework, Investigating
3. Process Skills: Oobleck	Investigating oobleck based on on the senses	Natural and Processed Materials, Investigating
4. Process Skills: Bubbles	Investigating bubbles based on focus questions	Natural and Processed Materials, Investigating
5. Process Skills: Classification	Classification of students and leaves	Life and Living, Investigating
6. Investigating Materials	Investigating the absorbency of materials	Natural and Processed Materials, Investigating
7. Sound: Discovery learning	Discovering how to make sounds from an audio-tape	Energy and Change
8. Rocks 1: Interactive	Rocks. Identify prior knowledge and generate questions	Earth and Beyond
9. Rocks 2: Interactive	Rocks. Groups answer questions from previous week	Earth and Beyond
10. Science and a story book	Demonstrating how science can be incorporated easily into story books	Life and Living

A summary of the four pre-service teachers is provided in Table 2. Pseudonyms have been used throughout. All four participants were female, ranging in age from 19 to 33 years. Three of the four participants had negative experiences with science at high school. All four participants had completed at least one science unit through to the end of their high school education. As can be seen from Table 2, each pre-service teacher had a different philosophy of teaching and learning at the time of this research. The pre-service teachers' aspirations for their future science students, while different, revolved around taking advantage of the curiosity of young children and enabling students to explore their world.

Data Collection and Analysis

Semi-structured interviews, based around an interview protocol (Kvale, 1996), were used throughout the study. The initial interview with the pre-service teachers concentrated on their previous experiences with science, their current attitudes towards science, and how they would like to teach science to future students. Subsequent interviews were held after each of the workshops. In these interviews the pre-service teachers were asked to identify and describe significant events or 'critical incidents' (Tripp, 1993) during the workshop that influenced them with regard to learning science or learning to teach science. Such critical incidents could relate to science content, pedagogy, epistemology, learning environment, teacher educator, or a combination of these. The influence of the events could be positive or negative. The pre-service teachers were also asked to explain why the events were significant to them, and how they could use these events to shape their future science teaching and learning. These

Table 2. Description of the four pre-service early childhood teachers

Pseudonym	Age	Perceptions of secondary science	Level of secondary science completed	Current philosophy of teaching and learning	Aspirations for their future science students
Sam	28	Negative experiences that were "untenable", "unconnected" and "abstract".	Year 11 & 12 Human Biology	Child-centred, child-generated, play-based.	Learn, value and be confident in science.
Ruth	33	Negative feelings: "rigid", "boring" and "scary". Ineffectively taught.	Year 11 & 12 Human Biology	Respect for each student and their individual needs and wants.	Use science as a tool for exploring the world.
Shannon	20	Human Biology was "interesting and easy". Felt "abandoned by teacher" in Physics, so "lost motivation to study."	Year 11 & 12 Human Biology, Physics	Engaging and understanding the students. Knowing the students and their capabilities to maximize their learning.	Using their curiosity to make science accessible.
Michelle	19	"Always enjoyed science" in and out of school. "Loves being challenged with investigations" and continually "wants to know why".	Year 11 & 12 Physical Science	Hands-on, play-based learning through different experiences.	Develop an inquiring attitude to help them explore their own world.

questions provided an opportunity for the pre-service teachers to, firstly, connect with their prior knowledge and experiences, and secondly to connect with classroom science teaching and learning. In the last week of the semester the pre-service teachers were asked to describe their overall science learning journey across the science methods course.

Critical incidents were chosen as the method of data collection in this research as they tend to mark significant turning points or changes in a person or in some social phenomenon (Tripp, 1993). Critical incidents are not characterized as being 'critical' due to any drama or sensationalism attached to them. Rather, their criticality is based on the justification, significance, or meaning given to them by participants (Angelides, 2001). While incidents happen, critical incidents are produced by the way a given situation is viewed; hence a critical incident is an individual "interpretation of the significance of an event" (Tripp, 1993, p. 8). Critical incidents are thus primary data sources, giving insights into the participants' assumptive worlds in their own language and expression (Brookfield, 1990).

Written notes were taken during all interviews. This was considered a more appropriate method of data collection than the use of audio taping for three reasons. First, due to the pragmatics of the study there was ample opportunity provided to collect rich data from a variety of sources without the need for taping. Second, being a participant-observer provided the first author/primary researcher with an understanding of the context of the workshops that would not be possible through taping. Third, as not every word within the interview was considered important, the use of written notes based around an interview protocol was considered adequate to reconstruct the interview (Anderson, 1998).

Short narrative vignettes were constructed by the primary researcher from these interviews, each containing the critical incident identified by the pre-service teacher (Howitt, 2007). Each vignette incorporated enough local detail to provide authenticity and enough structure to identify the critical incident. Each vignette was then a constructed narrative account, based on actual events and written in the voice of the pre-service teachers, reflecting their language and their construction of reality. Through this approach, the vignettes captured the action and interactions within the workshops in a vivid and life-like manner (Wildy, 1999). Vignettes were written within one week of the pre-service teachers providing and explaining the critical incident.

The checking of the vignettes for authenticity was achieved through cycles of reflection (Wallace & Louden, 2000) from the pre-service teachers and the first author/primary researcher, using a second interview protocol from. Initially, the pre-service teachers checked each vignette for authenticity and changes were made to reflect any feedback. Changes ranged from single words, sentences and paragraphs within the vignettes, through to the title of the vignette. Once changes were made, the pre-service teachers would again check the vignette for authenticity. All comments were written down on the protocol form or the actual vignette. The pre-service teachers also wrote comments directly onto the vignette during these interviews.

Once a vignette was considered representative of the significant event, the first author interpreted the vignette from the perspective of pre-service teachers' growth as a science learner and teacher. This interpretation involved the five-phase heuristic approach of

immersion, incubation, illumination, explication, and synthesis (Moustakas, 1994). The pre-service teachers were then given the opportunity to read and reflect upon these interpretations, and suggest changes as before. Consequently, detailed audit trails (Yin, 2003) for both the construction and interpretation of the vignettes was developed during the research. This writing and checking of the interpretation of the vignettes took from 5 to 10 months, and involved from two to four cycles of reflection. This time frame allowed both pre-service teachers and the first author/primary researcher an opportunity to think about the experience and what it meant after the fact. Such an approach also permitted a more detailed understanding of the nature of the experience and more opportunity to uncover the meaning of the lived experiences (Janesick, 2000).

The iterative process used in both the construction and the interpretation of the vignettes allowed the pre-service teachers to become a silent author in the process, to take some ownership of the process, and assist in the co-construction of meaning and interpretation (Kvale, 1996). More importantly, in retelling the original story both the pre-service teachers and the researcher were allowed an opportunity for increased reflection, growth and change in the way they perceived their practice (Clandinin & Connelly, 1994).

As a means of performing a cross case analysis, common critical incidents (or themes) (Polkinghorne, 1995) were identified across all four pre-service teachers' science learning experiences. These common themes were then used to describe how teacher educators could better construct and manage border crossings into science pre-service early childhood teachers.

Results

Pre-service teachers' new views of science

All four pre-service teachers experienced new views of science and subsequently the teaching of science as a consequence of the science methods course. It is these new views that provide evidence of the initial border crossings the pre-service teachers experienced during the course. These new views are reflected in Table 3, which provide a summary of the critical incidents for each of the four pre-service teachers during the science workshops. Each pre-service teacher is discussed in turn, to illustrate both the critical incidents and the changes within the teacher. While all four pre-service teachers acknowledged their views of science had changed during the methods course, each teacher had changed in a way that reflected their unique prior knowledge and experiences with science.

The second column in Table 3 provides a summary of Sam's critical incidents across the science workshops. Sam's critical incidents revolved around the importance of connecting with science, and the new views of science she was experiencing. Not only did Sam connect with science herself during the workshops, she identified the importance of connecting children with science if they are to develop positive attitudes towards science. Sam understood the importance of the teacher "understanding the child and connecting with what children know" (Interview 19/3/05). Sam's new perspectives towards science included viewing it as simple, fun, subtle, safe, play-based, and a realisation that science is everywhere. Other critical incidents, as illustrated in Table 3, included the role of questioning in science, self-discovery of science concepts, and the role of the senses during the workshops. Over the entire science learning journey, Sam believed she had increased her confidence and attitudes towards science due to the

Table 3. Summary of the critical incidents for the four pre-service teachers across all workshops

Workshop	Sam	Ruth	Shannon	Michelle
Oobleck	Connection between science and literacy New view of science: simple	Inclusivity as a pedagogical tool	Role of play Being allowed to feel like a kid Disguising science	Questioning as a pedagogical tool Challenging of thinking Simple has become complex
Bubbles	Importance of questioning in science	Cooperative learning experiences Sharing experiences Time to play	Thinking differently Imagination	Questioning Simple has become complex
Classification	Self-discovery New views of science: simple, subtle and safe		Active participation Discovery Ownership	Self-discovery Simple and complex at the same time Open-endedness New view of science: no wrong or right
Materials		Ownership Routineness	Open-endedness Different approaches to answering the same problem	Questioning as an investigative tool Simple to complex
Sound	Disconnected lesson Importance of connecting children with science	Connecting play with science teaching and learning Use of the senses as a pedagogical tool	Opportunity to explore Frustration at not engaging with activity	New views of science: soft, subtle, imaginative Connection between science and art Disguising science
Rocks	Role of the senses Connecting senses and questioning	Uniqueness of rocks Use of senses Connection between language and science	Uncertainty Consequences of uncertainty	Interactive Ownership
Learning journey	Whole immersion into science Thinking like a child Time and opportunity to connect with science	Right amount of science Simple/uncomplicated science Use of the senses Experience like a kid	New views of science: informality, exploration, discovery Pedagogical strategies Simple science	New view of science: dichotomies Becoming a part of the science Pedagogical strategies

"whole immersion into science" (Interview 14/10/04) that allowed her time and opportunity to connect with science. She also commented on the importance of being provided with the opportunity to "think like a kid" (Interview 14/10/04) and to therefore perceive science like a child does (see Table 4).

The third column of Table 3 provides a summary of Ruth's critical incidents across the science workshops. Ruth's major incidents revolved around inclusivity, and her desire to see all children participate equally and experiences success in science. Ruth believed it was important for "all students [to] have the opportunity to learn science [through] hands-on experiences" (Interview 3/8/05), which "incorporate all the senses" (Interview 26/5/05) and are "fun, uninhibiting and inclusive" (Interview 5/5/05). She found that facilitating science to young children which had no right or wrong answer was a means to ensuring "confidence in students through success" (Interview 23/3/05). Ruth's new perspectives of science included inclusive, informal, hands-on, fun, flexible and creative. Other critical incidents identified, as illustrated in Table 3, were the importance of connecting science with both play and with language, and the use of the senses during the workshops. Over the entire science learning journey, Ruth believed that the balanced approach to the science workshops, the simplicity and uncomplicated nature of the science activities, the use of the senses during the workshops, and the opportunity to experience what a child might experience, were most important in shaping her new views of science (see Table 3).

The fourth column of Table 3 provides a summary of Shannon's critical incidents across the science workshops. Shannon's critical incidents revolved around active participation in science that allowed for exploration and (self) discovery. Shannon acknowledged the importance of science in the primary curriculum, and the need for both teachers and children to explore and discover the (sometimes unknown) world of science together. She found that the "hands-on exploration along with discovery and discussion" (Interview 19/8/04) showed her how to access science. The informality of the science presented during the workshops also provided a means for Shannon to view science in a different manner to her previous experiences. Shannon's changing views of science teaching and learning were acknowledged when she stated, "I forgot that you can let the kids investigate and discover stuff, like we did in some workshops. There was no formal experiment there, we just got to muck around and explore" (Interview 21/10/04). Over the entire science learning journey, Shannon believed the most significant factors were her new views of science (informal, exploration and discovery), simplicity of the activities, and the pedagogical strategies presented during the workshops (see Table 3).

The fifth column of Table 3 provides a summary of Michelle's critical incidents across the science workshops. Michelle's critical incidents centred on her questioning nature, and her understanding that she "will be learning about science for the rest of my life" (Interview 4/1/05). Other major incidents related to the dichotomies that Michelle experienced during the workshops. Michelle experienced a simple/complex dichotomy in relation to activities, questioning, and interpreting the science activities in three workshops, where a simple idea led to a more complicated activity, question or explanation. Michelle's new perspectives of science included soft, subtle, imaginative, no right or wrong, and ownership. Over the entire science learning journey, Michelle found the contrasting features of the workshops allowed her to be part of the science. Commenting on the workshops, Michelle stated, "We did theory and practice. We did everything. We did both sides of the coin at the same time in the semester and generally

in the same lesson" (Interview 21/10/04). Michelle also noted that she understood the "teaching strategies better as I have seen them in action and been a part of them" (Interview 21/10/04).

Common Themes to Perceiving Science Learning Experiences

Various common themes as to how the pre-service teachers perceived their science learning experiences can be identified from Table 3. These include simplicity, inclusivity, open-endedness, making connections, 'disguising' science, and immersion into science. Each of these themes is discussed below.

Simplicity

The simplicity theme emerged from the first workshop with all four pre-service teachers referring to it at some stage during the methods course. Simplicity refers to two aspects within the workshops. The first and predominate aspect is taking a very simple or uncomplicated idea or activity and using it to teach science. This was evident with the oobleck workshop (using the senses to describe the mixture of cornflour and water), where all four pre-service teachers commented on the simplicity of the activity and the process. Similarly, the classification workshop (collection and classification of leaves) also was considered a simple activity that could be used for effective science teaching and learning in the early childhood years. It was this simplicity that became a major characteristic for Sam. Further, Ruth and Shannon both used this simplicity to describe their overall science learning journey. Both Ruth and Michelle described the second aspect of simplicity, when they referred to using simple methods to perform an investigation rather than sophisticated methods. Simplicity, in its various forms, was a significant theme to emerge from the workshops for all four pre-service teachers.

Inclusivity

Inclusivity, like simplicity, also referred to different aspects of the workshops. The predominant aspect of inclusivity referred to all children being able to perform and experience success in all science activities. Sam called this 'safe and accessible' science during the classification workshop, linking it with student-centred, student-directed and play-based learning. Ruth saw this inclusivity as a means of developing confidence in science, where both time and opportunity are provided for hands-on activities incorporating the use of the senses.

A second aspect of inclusivity was the importance of cooperative learning experiences and the sharing of ideas, information, discussions and reflections both within and across groups during the workshops. All four pre-service teachers, to varying degrees, commented on the importance of a discourse community within the workshops. A learning environment that reflected social constructivism, where many ideas were developed, discussed and shared, provided a means for these pre-service teachers to access science. Placing emphasis on science process and pedagogy, along with science content, has allowed such an environment to be developed.

The third aspect of inclusivity was identifying how it was used within the workshops as a pedagogical tool. This third aspect highlights the importance of the teacher educator not only modelling appropriate science teaching and learning strategies, but also providing explicit opportunities for the pre-service teachers to reflect upon these strategies and their effectiveness. While most of the pre-service teachers described at

least one of these aspects of inclusivity, Ruth described all three aspects. Inclusivity became the dominant characteristic for this preservice teacher.

Open-endedness
As the workshops progressed through the methods course, the open-ended nature of the activities became a theme identified by all the pre-service teachers. Various ways of describing this open-endedness emerged: having no right or wrong answer, having no one way to perform an activity or investigation, allowing for many different views to be expressed, and allowing for exploration, creativity, and self discovery. All the pre-service teachers acknowledged that these characteristics would allow students to take ownership of their own learning. The open-ended nature of the classification, materials (determining which of six materials would protect them most from water) and sound (manipulating objects to duplicate the noises from an audio tape) workshops was the cause of the new views to science that Michelle experienced. As a characteristic, the acknowledgement of open-endedness, discovery and exploration was most apparent in Shannon.

The emergence of the three themes of simplicity, inclusivity and open-endedness indicated that the pre-service teachers' understanding of nature of science was challenged during the workshops. This comment is based on the assumption that their views of nature of science would have been mostly based on their high school experiences. The workshops illustrated to the pre-service teachers that science is not just the domain of the clever (simplicity, inclusive), does not just use the scientific method (open-endedness), that there does not have to be only one answer (open-endedness), does not have to be complicated (simplicity), is not just a body of knowledge (inclusive, open-endedness), can be creative (inclusive, open-endedness), and can reflect social and cultural characteristics (inclusive).

Making connections
Making connections was another theme to emerge from the workshops. The pre-service teachers mentioned many different aspects associated with making connections. Connecting science with other learning areas was recognised by Sam, Ruth and Michelle as an effective means to teach science. These pre-service teachers commented on the connection between science and literacy in the oobleck and rock (describing rocks with the senses) workshops, and the connection between science and art in the sound workshop. Connecting with other learning areas allowed the pre-service teachers to draw on their prior knowledge in areas that they considered to be their strengths as a means of engaging, investigating and interpreting science. This active construction of knowledge allowed the pre-service teachers to more readily experience success in an area (science) they considered themselves to have limited confidence.

For Sam, making connection between science and literacy was a critical aspect of the development of her new views to science. Sam also identified other forms of making connections: connecting children with science, and connecting senses with questioning. The former comment relates to effective means of engaging students in science, while the latter relates to pedagogical strategies to incorporate within science teaching and learning. Ruth commented on the importance of making connections between play and science teaching and learning. This comment relates directly to the important place of play within early childhood education, and the acknowledgement by Ruth of the association between play and science education.

All four pre-service teachers made connections between the science learning experiences provided within the workshops and their future teaching. Such comments illustrate the growing maturity and reflection of these pre-service teachers, as they attempted to translate their science experiences into the future school classroom. Acknowledging they would be prepared to use a given workshop as is, or with modifications they suggested, illustrates a growing confidence within the pre-service teachers in their science teaching and learning.

'Disguising' science

Sam, Shannon and Michelle identified the theme of 'disguising' science. This theme could be interpreted in two ways. The first interpretation relates to the potential to integrate (or connect) science with other learning areas, as discussed in the above section 'Making connections'.

The second interpretation is more compelling, and was described by Shannon (in the oobleck workshop), when she referred to disguising science as not labelling activities as science. By deliberately not mentioning the terms 'science' or 'experiments', but instead just performing activities, there is no stigma, label or expectation attached to those activities. 'Disguising' science became an important component in assisting Shannon to improve her confidence towards science. For the pre-service teachers this meant feeling safe and comfortable in what could be regarded as an 'hostile domain'. Through engagement and exploration of science in an indirect manner, then followed by scientific explanation, science was made accessible to these pre-service teachers. This is consistent with Appleton's (2003) suggestion of presenting science content within a pedagogical context. Young and Kellogg (1993) noted the importance of non-scientific language, when explaining concepts, to assist pre-service teachers' learning. Fleer (2006) also supported the idea of not presenting science as something on its own, but rather pulling it together with the other concepts attached to teaching children. Within the science workshops, the learning environment was dictated by the choice of activity and corresponding teaching strategies employed. Activities that integrated with other learning areas (such as the oobleck and sound workshops) were not perceived as being 'hard science' by some of the pre-service teachers, and may have allowed these teachers to observe a more acceptable means (to them) of teaching science to young children. This in turn made the activity more accessible, enjoyable and relevant to the pre-service teachers. In this context, the theme of 'disguising' science can be seen as more of a pedagogical strategy appropriate to early childhood teaching and learning contexts, rather than an avoidance of science.

Immersion into science

The final theme identified from the workshops was immersion into science. This immersion was in the form of being provided with opportunity to play and explore, allowing them to experience science through the eyes of a child. All four pre-service teachers commented on this theme in some manner. By allowing the pre-service teachers both time and opportunity to play and explore like children do, they rediscovered the excitement and curiosity associated with young children's science and gained a greater understanding of how children learn. Zembylas and Barker (2002) identified the importance of providing pre-service teachers space, time, and encouragement to play and discover, and being able to see through the eyes of a child. However, the immersion into science theme suggests more explicit and detailed learning experiences, where informal role playing as a child, including touching, describing,

questioning, and general 'mucking around' allows the world of young children's science to become more of a reality.

The pre-service teachers witnessed both positive and negative experiences through the child's eyes. While most experiences were positive, both Sam and Shannon found themselves disconnected from certain workshops for various reasons. For Sam this happened in the sound workshop, while for Shannon this happened in the sound and the rocks workshop. The negative experiences provided these pre-service teachers with a unique insight into the disinterested or subdued child's world. It also provided an ideal opportunity to reflect on how and why such children might become disconnected, and as teachers what they could possibly do about such situations. In this regard, the negative experiences these two pre-service teachers experienced were transferred into positive ones through reflection. The immersion into science through child's eyes was another major part in developing the pre-service teachers' confidence towards science.

Common critical incidents
With the exception of one workshop, all four pre-service teachers had different experiences and significant events throughout the workshops. The workshop on classification (collection and classification of leaves), which was delivered as an example of constructivist teaching and learning, was significant to all the pre-service teachers due to the self-discovery they experienced. Given the open-endedness of the workshop, different constructions that were possible, and the different levels of prior knowledge the pre-service teachers brought into the classroom, it was surprising that all the pre-service teachers identified the same significant event. However, this also could have been the first time they had seen a constructivist science lesson, and perhaps the first time they had been given the opportunity to connect the constructivist theory with practice. This highlights the necessity to convert science education theory into practice to make it more accessible, explicit and relevant for pre-service primary teachers.

Discussion

Implications for early childhood science teacher education
Pre-service teachers require suitable border crossings into science to help them gain confidence in both science and the teaching of science. The themes identified above provide a means for teacher educators to better construct and manage border crossings for the pre-service teacher from early childhood education to science education. Two general assertions are presented below to assist this process, framed in terms of the pre-service teachers' changing representation of, and changing perceptions of their identify in, science and science education (Barton, 1998).

Assertion 1: The science methods course should develop a more realistic representation of science suitable to the pre-service early childhood teachers' needs
The learning experiences presented in the science methods course clearly challenged the pre-service teachers' view of science. That was part of the aims of the methods course. Rather than perceiving science as something complex and abstract as they did in high school, which could not be taught to very young children, the pre-service teachers have been presented with a different representation of science. Through the use of authentic science learning experiences situated within an early childhood context, the pre-service teachers have seen that science can be taught to very young children, can be presented in a simple manner, can be inclusive (where all can and do succeed), can be open-ended

(where there is no right or wrong answer), and can be integrated. Clearly demonstrating to the pre-service teachers what early childhood science 'looks like' provided them with a new lens from which to view the destination of their border crossing.

In order for border crossings to be powerful for the learner, Lee (2003) noted that the individuals doing the crossing need to be made explicitly aware of the borders and the means by which they are navigating the crossing between those borders. Providing the four pre-service teachers with weekly opportunities to reflect on and articulate their own science learning experiences, as part of this research, resulted in them being more aware of their own personal growth over the science methods course, along with developing their personal reflective skills. This reflection assisted them in making explicit the origins and the destination of their border crossings. It also provided an opportunity for them to express their feelings about such destinations, and how they personally view and place that destination in relation to their developing philosophy of early childhood teaching and learning.

Assertion 2: The science methods course should assist in developing a more realistic image of the pre-service teacher's successful participation within their new image of science

The pre-service teachers were further challenged in their belief of how they could engage in science. Allowing the pre-service teachers the opportunity to explore and play, as young children do, demonstrated the fun and engaging aspect of teaching and learning science, and illustrated the importance of sensory-based experiences and observations within early childhood education. The provision of space, time and opportunity to play and discover within the science methods course allowed the world of young children's science to become a reality to the pre-service teachers. Such first hand experiences with science teaching and learning provided a means for these pre-service teachers to access science, and to start questioning their place in that science.

The use of a social constructivist approach within the workshops allowed the pre-service teachers to not only be a part of the process but to consider it as an effective science teaching and leaning pedagogy. By employing an inquiry approach to science, incorporating a variety of student-centred, hands-on and cooperative learning experiences, the pre-service teachers were presented with new strategies on how to teach science that were in accordance with their views on early childhood education. Experiencing and discussing these strategies first hand within the science methods course allowed the pre-service teachers an opportunity to discuss how their views of teaching science were changing, and how their attitudes and confidence towards science were changing.

Limitations of the Study

While the findings of this research are based on four detailed case studies, there are various limitations attached to them. Even though the cases provided variation in age and confidence towards science, it is possible that other pre-service teachers may have identified different critical incidents within the workshops. Similarly, the individual case studies may not have been representative of the broader population of pre-service primary teachers.

While this research provides evidence of the initiation of border crossings within the pre-service teachers, it provides no indication as to whether such progress of crossings

is maintained, increased or diminished once in the classroom. Border crossings observed within the context of a pre-service education course do not necessarily transfer into teaching practice (Wideen, Mayer-Smith, & Moon, 1998). Following these pre-service teachers into the classroom would provide valuable information on how the learning experiences of a science methods course translate into teaching and learning, along with information on how teacher educators could better manage the border crossing from pre-service to in-service teaching.

Conclusions

This research adds to the limited knowledge on how the role of experiences within teacher education programs facilitates the development of professional knowledge (Bryan & Abell, 1999). Specifically, this study provided a highly personal and detailed insight into how pre-service early childhood teachers perceived their science learning experiences within a science methods course, and how those experiences contributed to their changing views of science and science teaching. Each of the four pre-service teachers perceived their science learning experiences differently. Each pre-service teacher experienced new views towards science and subsequently science teaching as a consequence of their learning experiences.

The common themes of simplicity, inclusivity, open-endedness, making connections, ‘disguising‘ science, and immersion into science provide a means for the teacher educator to initiate smooth border crossings from early childhood education into science education for pre-service teachers. The learning experiences associated with such border crossings should demonstrate to the pre-service teachers the accessibility of science teaching and learning. As a consequence of this, the learning experiences should also assist the pre-service teachers to start developing more positive attitudes and increased confidence towards science and science teaching.

The border crossing metaphor provided an effective framework for explaining and interpreting the science learning experiences of these pre-service primary teachers, as they came to learn about science and science teaching. This framework highlights the importance of the teacher educator in managing the pre-service teachers’ crossings, and the place of explicit reflection within this process. Increasing the degree of overlap between pre-service teachers’ entry beliefs and experiences and the learning experiences in the science methods course becomes a bridge to enabling more effective border crossings.

The common themes identified illustrate the necessity for the teacher educator to adapt science to the needs of the pre-service teachers, rather than simply urging the pre-service teachers to become more scientific in order to adapt themselves to science (Mulholland & Wallace, 2003). To achieve this, the borders between early childhood education and science education will become blurred. As pre-service teachers construct meaning of how to effectively teach science within an early childhood context, they must also find their own identity and place within that science.

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