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Pre-Service Teachers' Views of School-Based Approaches to Pre-Service Primary Science Teacher Education

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Abstract Primary pre-service teachers (PSTs) in Australia often have low confidence and negative experiences in relation to science and teaching science. This paper reports on pre-post survey data produced by four institutions involved in a multi-institutional project exploring the use of university-school partnerships for primary science teacher education. The findings show that the experience of engagement in school-based science teaching contributed to the development PST classroom readiness particularly with respect to statistically significant increases in confidence. We argue that moving tutorials from university into schools supports PSTs' engagement with the teaching profession and teaching science.

Keywords Primary school · Science education · Pre-service science teacher education · Partnerships

Introduction

Initial teacher education plays an important role in preparing confident and passionate teachers; however, the learning needs of pre-service teachers (PST) are influenced by their background, especially in relation to science. Whilst secondary science PSTs have a background in, and a commitment to, the subject they are likely to teach, in Australia, primary teachers are usually prepared as generalists. Research has shown that primary PSTs are less likely to have had positive experiences of science in high school and often lack confidence to

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learn and teach science successfully (Akerson 2005; Tytler 2007). Science pedagogy units, therefore, play an important role in challenging these poor attitudes towards science, such as through providing tailored science content courses (Palmer et al. 2015); using school-based experiences within university-school partnerships (Jones et al. 2016; Jones 2008; Kenny 2009, 2010; Peterson & Treagust 2014) and an emphasis on discussion, debate and argumentation around collaborative problem solving (Watter & Ginns 2000). In this paper, we provide data on an emerging trend (Kenny et al. 2016) to provide PSTs with opportunities to teach science to primary students in order to gain an *authentic* experience of learning and teaching.

Rather than relying on the formal placement to offer such experiences, there appears to be a shift in science teacher education towards situating learning experiences within schools as a way of linking pedagogical theory with teaching practice (Jones 2008; Kenny et al. 2016). Peterson and Treagust (2014) recommend that PSTs need more time observing science being taught and teaching science whilst being supported by teacher educators. Teacher educators are university lecturers and tutors, or practicing teachers and retired teachers working for the university, who deliver university content. Notably, they state that reciprocal relationships between universities and schools are needed in primary science education to improve science teaching in schools. In teacher education, such experiences are tending to be *in addition to* the formal practicum arrangements; this is because PSTs often have little or no opportunity to teach science during the practicum (Tytler 2007).

These moves to embed PST learning in schools are in keeping with the latest report from the Teacher Education Ministerial Advisory Group (TEMAG 2015). Criticism of a supposed gap between theory and practice in teacher education has mobilised universities to reconsider how partnerships are used in teacher education. The TEMAG report stated, “theory and practice in initial teacher education must be inseparable and mutually reinforced” (TEMAG 2015, p. 18). Strong relationships between schools and universities are crucial in achieving this outcome (TEMAG 2015; OECD 2014). Recent research has begun to report ways in which effective school-university partnerships might be developed. For example, in their work investigating the connections between school-university science partnerships and their impact on science teaching efficacy, Peterson and Treagust (2014) argue that “universities and primary schools need to develop reciprocal relationships in the area of science education” (p. 162).

The Australian Office for Learning and Teaching has responded to these concerns by funding the Science Teacher Education Partnerships with Schools (STEPS) Project, which investigated the effectiveness of five universities’ established, innovative and successful school-based approaches to pre-service primary science teacher education (Hobbs et al. 2015). At each university, a core or elective unit included experiences where PSTs taught science to students over a number of weeks in local primary schools. In order to generate data on their expectations and experiences of the programs, PSTs at each university undertook online surveys before and after completing the units involving these school-based experiences. The surveys captured both quantitative and qualitative data. In addition, interview data were collected from teacher educators involved in the programs at the participating universities, principals and school teachers from partner schools and teacher educators at other institutions around Australia.

This paper reports on the analysis of PSTs’ responses to the online pre- and post-surveys. As a context for the study, a review of the literature concerning science education examines why such school-based approaches to teacher education have become so important in dealing with the issues now facing the preparation of primary teachers to teach science. This review is followed by details of the data collection and analysis. Results are presented and discussed to provide insights into the features that have contributed to the overall success of this school-based approach to science education for these primary PSTs. Finally, our conclusions will draw attention to critical factors for the implementation of similar school-based approaches, in particular the importance of utilising partnerships between schools and universities where PSTs are supported by teacher educators in making meaningful links between theory and practice.

Background

Primary Science Teaching in Australia

Various reviews on science education have declared the need to improve primary science, both in quality and quantity (Australian Science Teachers Association (ASTA) 2014; Chubb 2013; Marginson et al. 2013; Tytler 2007). In Australia, ASTA's (2014) national primary science teacher survey revealed that science is taught for only 2% of the total teaching time nationally, more specifically on average between 1.3 hours per week (in the state of Victoria) and up to 1.9 hours per week (in Tasmania and Western Australia). In Victoria, 29% of respondents taught science for less than an hour per week.

This unwillingness to make substantial time available for the teaching of science in primary schools has implications for how well young people are prepared for an increasingly science-dependent society, a trend that underpins the rhetoric around the science, technology, engineering and mathematics (STEM) agenda. There is growing concern regarding skill shortages in science-based areas both nationally and internationally (Commonwealth of Australia 2011; Osborne et al. 2003), with 75% of the fastest-growing occupations in the future requiring skills that can be associated with the STEM disciplines (Australian Industry Group 2013). These shortages are related to a *crisis* in science education, which is comprised of five interrelated problems: negative student attitudes towards school science (Lyons and Quinn 2014), decreasing participation in post-compulsory science subjects, a projected skills shortage in science-related fields, a shortage of qualified science teachers and less than effective science teaching practices in primary schools (Marginson et al. 2013; Murphy & Beggs 2003; Osborne et al. 2003; Tytler 2007; Tytler et al. 2008; Chubb 2013).

Darling-Hammond (2000) asserted that the development of students' understanding is fundamentally tied to the quality of teaching; therefore, primary teachers' lack of science knowledge and confidence to teach science (Jones & Carter 2007) has the potential to severely limit growth in understanding science concepts and practises. In addition, the common practice of integration, where multiple learning domains such as science are integrated into units of work, has contributed to science's lack of prominence in the primary curriculum. It is not surprising that this has led to the limited time spent teaching science in primary schools (Goodrum et al. 2001b; Keys 2005; Tytler et al. 2008). As illustrated by Preston et al. (2007, p. 29):

> In busy classrooms with an overcrowded curriculum where student teachers frequently report scant time allocation for science lessons … [r]estrictions on the amount of time available for teaching science lessons in schools arise due to timetabling constraints and the perceived priority of other curriculum areas.

The crisis in science education is not new. In 2001, Goodrum et al. (2001a, b) undertook a review of science education in Australia. This review found that there was a stark difference between what was considered to be the "ideal picture" of teaching and learning science compared with the "actual picture". The ideal picture was heavily predicated on "the belief that scientific literacy is a high priority for all citizens" (p. 5), which would help students be interested in and understand the world around them; to engage in the discourses of and about science; to be sceptical and questioning of claims made by others about scientific matters; to be able to identify questions, investigate and draw evidence-based conclusions and to make informed decisions about the environment and their own health and well-being (Goodrum et al. 2001a, b, p.10).

In order to achieve this ideal, Goodrum et al. (2001a, b) identified nine themes characterising quality science education: relevance of the curriculum for students, use of inquiry where students investigate and construct ideas and explanations, assessment practises that add to learning; positive and motivating teaching-learning environment, teachers as life-long learners, professional standards, availability and quality of resources and facilities, reasonable class sizes, and valuing of science and science education. They also claimed there were three main reasons affecting the quality of science teaching in primary schools: resources; teacher factors including lack of preparation time, teachers' science content knowledge and limited availability of professional development; and the priority accorded to science because of an overcrowded curriculum and time.

Six years later, Tytler's (2007) analysis of science education revealed that circumstances reported by Goodrum et al. (2001a, b) remained much the same, particularly in relation to what science is taught, teaching and assessment for science, student participation and achievement, constraints (such as teachers' knowledge) and PST training. He claimed that the same barriers still existed for effective teaching of science in primary schools. Tytler's report challenged the current conventions in science education and proposed new directions for science teaching and learning. Tytler proposed a "re-imagined science curriculum" (cf. Goodrum, Hackling & Rennie's Ideal picture) focused on humanising school science to improve students' understanding of the world around them and assisting them to make rational decisions on important issues. He asserted that science education should be about the "spark of excitement" that stems from discovery, with relevant open-ended, rather than prescriptive, tasks and that teacher confidence and professional development is just as important as the learning materials. For such a vision to be achieved, teachers therefore need to model such excitement and take on seriously the task of teaching science. For PSTs who often have little history of being committed to science, and who have little experience of being excited and confident about teaching science, it is essential that they are given the opportunity to delve deep into science themselves and discover the joy that science can bring.

Recent PISA and TIMSS international tests (reported in Marginson et al. 2013) indicate a need for change to arrest the falling performance of Australian students in science and mathematics on these tests. Also important is reversing the falling participation rates of young people in STEM (Chubb 2013), which appear to be affected by identity-related issues influencing subject choice at senior school (Lyons & Quinn 2014). The former Australian Chief of Science, Ian Chubb, called on the education sector to help meet the declining interest in STEM careers, stating that "[i]nspirational teaching at school is crucial for nurturing student interest in science and influencing their study and career choice" (Chubb 2013, p. 14). He recommended that "[t]eaching time devoted to science (as *science*) should be increased in primary schools from an average of less than five per cent to closer to the Western European average of nine per cent" (p. 14). Twelve years earlier, Rennie et al. (2001) recommended improved funding for science teacher education, and the provision of coordinated professional development opportunities in science education, supported by the education jurisdictions.

Similarly, Chubb called for improvement in pre-service and in-service teacher support to ensure teachers are "well-versed in STEM disciplines" (p.14). However, missing from these recommendations are the relationships between universities and schools in providing professional development for schools and supporting the effective preparation of the next generation of teachers.

We argue that these issues of time and supported engagement with science education in PST education can be attained by partnerships between schools and universities, aiming to provide PSTs with real opportunities for planning, implementing and evaluating science lessons through what might be considered action research cycles (Carr & Kemmis 1986) whilst being supported by teacher educators. Through these programs, in-service teachers are exposed to current theories informing science teaching practice, and PSTs' fears and lack of confidence about science and teaching science can be at least partly addressed.

Confidence to Teach Science

According to Kidman (2012), many primary teachers feel inadequately prepared to teach the inquiry component of the *Australian Curriculum: Science* (ACARA 2016), which is particularly represented through the science inquiry skills. Factors such as science content knowledge and a lack of pedagogical skills to develop open inquiry lessons are cited as hindering the effective use of scientific inquiry in the classroom, both of which are at the core of any science program. Research has shown that PSTs often come into teacher education with a poor science background and low confidence to teach primary science, particularly when faced with the reality of running science experiments (Jones & Carter 2007). These apprehensions can tend to persist after graduation (Cooper et al. 2012; Gess-Newsome & Lederman 2001).

Confidence to undertake a task is affected by an individual's self-efficacy (Bandura 1989), that is, their belief in their ability. It influences PSTs' motivation and engagement in teaching and learning science (Odgers 2007). Consequently, "[a] common challenge for many primary PST educators is to rekindle interest in science content among future teachers who often express a lifetime of negative associations with school science" (Gilbert 2013, p. 6). Taylor and Corrigan (2005) reported on a study exploring the implementation of a 13-week program of self-regulated learning with 19 PSTs in a first year, primary science education course. The program offered PSTs substantial flexibility and freedom in what they investigated and the methodology they adopted, coupled with ongoing support as required. By the end of the program, the majority of PSTs involved in the study reported a more positive attitude to science and significantly enhanced confidence in their ability to teach primary science. Although difficult to measure, PSTs believed that they were more competent to teach primary science. Furthermore, they were able to identify aspects of the self-regulated learning environment that had contributed to this change in attitude. This link between confidence and feelings of competence to teach science, that is self-efficacy, is an important marker in the shift from learning to teach science to teaching to learn. Accordingly, an individual's perceived efficacy becomes a strong determining factor in the types of activities and settings individuals elect to participate in (Bandura 1989), their resilience and perseverance to overcome perceived barriers (Goddard 2003) and the types of strategies with which they select to teach science (Jones & Carter 2007).

Building PSTs' confidence and self-efficacy was a motivation for the teacher educators in the study reported in this paper to reconfigure their science education programs to include what Bandura (1989) calls mastery experiences, which are experiences of personal accomplishment.

Opportunities to succeed in learning and teaching science should build confidence and therefore self-efficacy. As a result, PSTs' willingness to plan and conduct science lessons should increase as should their selection of appropriate science teaching strategies, both now and after graduation. We argue that opportunities for mastery experience arise when PSTs teach science to students and when such experiences are embedded within science method units rather than expecting them to arise within the formal practicum.

School-Based Approaches to Pre-Service Science Teacher Education: the *Practicum* versus an Approach to Science Education

As has already been argued, a rationale behind using the school-based approach is to attend to PSTs' lacking confidence in their knowledge and ability to teach science (Gess-Newsome & Lederman 2001; Kenny 2010; Palmer 2006). Taking the PSTs into the school environment provides access to primary school students and teachers and a chance to teach science in a school environment and thereby, hopefully, to experience the challenges and joys of teaching science. We are referring here to the provision of such school-based learning experiences during a science method unit that would normally be delivered on university campus or online, in addition to the formal practicum that usually runs concurrently to the university-based units or as blocks of time in schools.

Several studies have explored the effectiveness of school-based approaches to PST education (Adey & Speedy 1993; Allen et al. 2013; Burton & Greher 2007). Many of these focus on different models of formal practicum. Whilst our study does not focus on the formal practicum, we can draw from some of this literature in order to understand how to maximise the benefit of school-based approaches to science teacher education.

Effective university-school partnerships are essential to both successful practicum models and for running school-based science teacher education. Admiraal et al. (2012) developed a set of principles for developing school-university partnerships. They advised that "student-teacher communities can prepare student teachers for their participation in teacher communities in their future professional lives" (p. 275). PSTs' inclusion in teachers' learning communities may also assist them to integrate into school communities on completion of their tertiary education. Reciprocally, there is potential for the classroom teacher's personal development to be supported by the teaching modelled by the PSTs. Indeed, Hamel and Ryken (2010) highlighted the potential for cross-fertilisation of expertise when intentional school-university partnerships involve dialogue between experienced teachers, teacher educators and PSTs. When the PSTs' experiences are "discussed openly with both generosity and scepticism" (p. 335), the complexity of teaching can be interrogated by all parties. These studies highlight the benefits of having meaningful interactions between school teachers and the PSTs.

Other practicum models highlight important factors in maximising the benefits for teachers and PSTs. Adey and Speedy (1993) described the development of a 1-year *end-on* teacher education program used by graduates following the completion of a degree at the University of South Australia. They found that it was important to: embed the program in a genuine partnership between the schools and the university, recognise teachers who acted as mentors to the PSTs, allow PSTs to take on the role of interns engaging in all aspects of school life, provide a framework for PSTs to explicitly link theory and practice and promote teaching and learning that focuses on "student inquiry and reflection" (p. 35). Allen et al. (2013) reported on an effective partnership which contributed to the preparation of PSTs. The partnership focussed on "addressing the gap between theory and practice" (p. 99) and determined several factors which contributed to the success of the program: "coherence and alignment between schools and the university, communication, logistics/systemic considerations, [and] equity issues" (p. 104).

Some models of a school-based approach focus on immersion of PSTs in the professional culture of teaching generally (see, for example, Admiraal et al. 2012; Buitink 2009; Hamel & Ryken 2010), whilst others allow for subject-specific teacher development (see, for example, Hardy & Kirkwood 1994; Howitt 2007; Kenny 2010; Peterson & Treagust 2014; Preston et al. 2006; Wingfield et al. 2000). The model of school-based experiences for PSTs described by Buitink (2009) differs in that primary PSTs are employed as a teacher in their fourth year of their initial teacher training. Nevertheless, their findings support the value of school-based experiences, indicating that the PSTs in their study "developed a practical theory in which they pay attention to pupils' learning" and that this was in advance of the usual development of beginning teachers where this awareness typically develops "generally not until after teachers have been working in the profession for a few years" (p. 125).

Common to the practicum models mentioned above is their potential for linking theory to practice in order to develop a practical understanding of theory and providing opportunity for meaningful interactions between PSTs, students and teachers. Turning to the specific instance of science teacher education, some instances for science teacher development may be embedded within the practicum, provided there is substantial teacher educator involvement in facilitating links between theory and science teaching practice. For example, Preston et al. (2006) reported that the problem of limited exposure to science teaching on practicum could be overcome by setting an assignment to be completed on practicum where PSTs are required to teach a sequence of science lessons. However, a school-based experience embedded within the science method units offers potentially more strategic and targeted learning experiences for PSTs.

Various models of the school-based approaches have been trialled. For example, Bottoms et al. (2015) describe a model where PSTs taught science to students in an after-school STEM club then reflected on their experiences on three occasions or "cycles" over 3 weeks. In the first cycle, PSTs elicited student's understanding; in the second cycle, they implemented an investigation and in the third cycle, they assessed students' understanding. Drawing on Lampert et al.'s (2013) "cycles of enactment", this model emphasises learning through participation within a professional learning community and immersion of PSTs in "the deliberate practice of teaching" (p. 719). Each cycle of enactment includes four phases where PSTs *deconstruct* the science standards to be taught and appropriate teaching approaches, *teach* the lesson, *reconstruct* the lesson with peers by reflecting on how the lesson went, then *analyse and interpret* their teaching by viewing video footage of the lesson focusing here on linking theory (from their readings) to their practice.

This model is similar to the STEPS approach reported in this paper where PSTs are supported by teacher educators to develop their understanding of science concepts and appropriate teaching approaches, implement a sequence of lessons and reflect on their practice. The STEPS models differ from Bottoms et al. (2015) in that PSTs spend 1 to 3 hours on location for an extended period of time—between 5 and 8 weeks, depending on the university—thereby plan, implement and reflect on a sequence of lessons more aligned with what they will be expected to do as teachers. However, common and pivotal to the STEPS school-based approach and that of Bottoms et al. (2015) is the role of the teacher educator in facilitating meaningful reflection that allows practice to be interpreted and understood through a theoretical lens. In this endeavour, the role of the teacher educator is crucial in supporting PSTs (Hardy & Kirkwood 1994; Howitt 2007) and for providing experiences that develop PSTs' pedagogical content knowledge (Kenny 2010).

Peterson and Treagust (2014) provide a literature review of the relationships between school-university partnerships and efficacy of PSTs, arguing that further research is needed to establish the benefit of such "reciprocal relationships in the area of science education" (p. 162). So, whilst the actual experience of teaching the students is expected to be of most benefit to PSTs, how the PSTs are supported to develop their content and pedagogical content knowledge and to reflect on their practice differentiate this school-based approach from the typical practicum. By way of setting an agenda for research, Burton and Greher (2007) reviewed literature relating to school-university partnerships, discussing problems and possibilities of collaborations in both general education and music education contexts. They proposed a research agenda focusing on "(a) the developmental nature of the collaboration process, (b) the quality of the process, (c) the outcomes of the process and (d) the perspectives of all parties involved to examine the role of school-university partnerships in music teacher education" (p. 13). This paper reports on PSTs' perceptions of their experience whilst engaged in a school-based unit in science education, thus responding to the research agenda proposed by Burton and Greher (2007).

Teaching Strategies Appropriate for School-Based Teacher Education

Whilst we are arguing for serious attention be given to school-based approaches as part of primary science teacher education, getting our PSTs into schools and working with children is only part of the process. Decisions need to be made about what teaching strategies can be promoted and used to build the PSTs' capacity and confidence to teach science. Reported are a variety of approaches used in primary science teacher education, for example, an emphasis on inquiry (Hackling 2010; Kidman 2012; Rodgers & Abell 2008; Taylor & Corrigan 2005) or the use of particular curriculum packages (Bottoms et al. 2015; Cooper et al. 2012; Jones 2008; Kidman 2012; Peterson & Treagust 2014; Preston et al. 2006; STEPS 2014). Each of these strategies or approaches are discussed below and linked to the school-based approach reported in this paper.

As an approach for science teacher education, inquiry provides a vehicle for students to understand and experience the process of undertaking science by participating in the practises of the science discipline. Hackling (2010) defined inquiry-based approaches with varying degrees of openness "from verification (where the problem, equipment, procedure and answer are given) to open inquiry, where all of the steps are open or negotiated" (p. 7). Some researchers described approaches that might be considered open inquiry according to Hackling's classification (Kidman 2012; Taylor & Corrigan 2005) whilst other approaches are guided inquiry (Rodgers & Abell 2008). Whilst there is ample evidence to show the benefits of inquiry approaches, Kidman's (2012) study showed that 60% of primary teachers agreed that the purpose of open inquiry is to "give training in solving problems and conducting investigations" (p. 44), but only 10% considered that its purpose was to "promote thinking in a scientific way" (p. 44). Research has shown that PSTs' content knowledge can impact on their ability to practice inquiry learning (Leonard et al. 2011), and that they "need to have focused science teaching time with primary students to strengthen and support their confidence, attitudes and abilities to implement inquiry learning" (Plevyak 2007, p.11).

School-based approaches enable PSTs to observe students bringing their science knowledge into the classroom, build on that knowledge through engaging and hands-on inquiry experiences, engage in deep thinking and some degree of cross curriculum integration. "Pre-service teachers emphasise interest and the enjoyment factor and fact verification through student discovery" (Kidman 2012, p. 36). When hands-on learning is the focus of science lessons, school students tend to react with excitement. This has immediate value for PSTs as they see the value of science for their students as well as how a more engaged learning environment can be fostered through science inquiry approaches.

Other researchers described the use of particular resources (Cooper et al. 2012; Hoban 2007; Kennedy-Clark 2011) in the teaching of science education to PSTs. Use of these resources tends to focus on building conceptual understanding, as well as knowledge of teaching strategies and the logistics and resources involved in teaching science. They therefore attend to some of those concerns that PSTs can have about content and resources. Cooper et al. (2012), for example, reported on the use of Primary Connections material (Australian Academy of Science 2005), which is a series of learning resources developed by the Australian Academy of Science based on the 5E Instructional model (Bybee 1989). They described how quality teaching resources can be embedded within a program of teacher education designed to encourage and support PSTs to embrace science teaching. Within the STEPS school-based models, all teacher educators used the *Primary Connections* materials to provide a model for how the PSTs can plan using the 5E instructional model. This structure and the detailed lessons plans are not necessarily simply implemented but act as a professional development tool.

Another aspect to teaching science as inquiry is through emphasising the affective aspects of the experience of learning about science teaching and learning. Gilbert (2013), for example, found that the notion of wonder could be offered to PSTs as a vehicle to develop more positive conceptions of science. He argued that school science should be conceptualised not just as a way to understand the world but also as a way to clearly demonstrate that it is a field of inquiry that is sustained by mystery, beauty and wonder.

Whilst the above research focuses on the use of specific approaches, we argue that they are powerful when incorporated within a learning program tailored to support PSTs to try out these approaches. It is through becoming proficient with these approaches that PSTs can have confidence in knowing how to approach a classroom with confidence and that they will be effective in engaging students in learning. The teacher educator's role is fundamental in selecting what strategies will work for PSTs' students, plan learning experiences that build capacity of the PSTs to use the strategies themselves and then to assist PSTs to reflect on their implementation of these strategies. Assessment tasks across all of the STEPS models require PSTs to illustrate a practical and theoretical understanding of the teaching strategies that they use.

Methodology

Context: the STEPS Project

The school-based approach is reliant on forming relationships. Communications between school communities, school teachers, PSTs, the university and teacher educators are critical. Partnerships lead to the sharing of learning and a growth in mutual understanding of the requirements to make the partnership function effectively. The aim of the STEPS project was to develop and promote an interpretive framework to support the implementation and maintenance of school-based approaches to PST education (Hobbs, et al. 2015; Jones et al. 2016). The project developed a set of guiding principles for university-school partnerships which support the science education of PSTs (Hobbs et al. 2015):

1. Embedded within a partnership between university and schools
2. A commitment to quality science education

3. Authentic interaction with children in schools for the purpose of bridging the theory-practice divide
4. Science teacher educator plays an active role in supporting the pre-service teacher in school settings.
5. Science teacher educator and pre-service teacher practice is informed by pedagogical and learning theories.
6. Interaction between pre-service teachers and children is integral to a science-related unit.
7. Involve planning, implementing and assessment of a learning sequence in science
8. Reflection on and articulation of practice that focuses on pre-service teacher development and identity and children's learning

The STEPS (2014) project brought together teacher educators from five universities where school-based science education approaches have forged stronger links for PSTs between theory and practice. In these programs, PSTs reflect on actual teaching experiences to develop teaching knowledge and ability (Loughran 2010) through the support and guidance of their teacher educators whose constructivist background has influenced the design of their school-based programs. In these particular programs, the classroom teacher has mostly assumed a supervisory role rather than actively engaged in mentoring the PSTs. Each university demonstrates a different model of university-school partnerships in science teacher education, depending on local contexts and reflecting teacher educators' knowledge and beliefs about science teaching and learning (see Table 1). A common feature of these models is the process of PSTs planning, implementing and reflecting on a series of lessons with primary school students similar to the approach taken by Bottoms et al. (2015). Each university devoted a number of weeks to this teaching program, mostly consecutive weeks but depending on university and school timetable constraints— for example, school holidays, school events and university holidays needed to be factored into the planning. Key to these models was the establishment of partnerships with schools (Kruger et al. 2009) based on a mutual recognition by both partners of their role they play in preparing the next generation of teachers.

The quality and success of these programs is demonstrated by high PST satisfaction ratings, the increased number of schools involved and the ongoing partnerships with schools that have been involved over many years. This paper reports on PSTs' perceptions of a school-based program of science education at four of the universities participating in the STEPS project. Survey data collected from University of Tasmania PSTs was generated in an earlier study because the science unit was not offered during the course of the STEPS Project; this data is not included in the analysis of this paper as it was generated using a different survey tool; however, the data is reported in Kenny (2009, 2010) and Kenny et al. (2014).

Surveys

In order to better assess the effectiveness of this form of pre-service science education, the voices of the PSTs were sought. They engaged in pre- and post-online surveys[1] generating data on their experiences and expectations associated with these experiences. The surveys were designed to include paired pre- and post-items in order to gauge change. Common items focused on confidence and motivation and included demographic data such as age and gender.

[1] Generated with Qualtrics, software, version 2013 of the Qualtrics Research Suite

Table 1 Similarities and differences between the programs at the different universities (STEPS 2014)

Case study	Deakin University	RMIT University	University of Melbourne	UTAS	ACU Ballarat
Course / Program	B.Edu (Primary)	B.Edu BEdu/Disab Masters of Teaching	B.Edu Masters	B.Edu	B.Edu (Primary) B. Early Childhood and Primary Education
Average number of PSTs/year	450	280	165	24	72
Time PSTs spend teaching science to primary students	8–9 × 1 h in a semester	4 × 2 h in a semester	9 × 1 h per year	Preliminary visit, 6–8 × 2 h in a semester	5 × 2 h in a semester
University tutorial	2 h of tutorial at school each week	1 h of tutorial at school during teaching weeks, university tutorials during non-teaching weeks	4 h of tutorial at university each week	3 h tutorials during non-teaching weeks	1 h lecture at university
Core unit/elective	Core	Core	Core	Elective	Core
Teacher educator present at school	Yes	Yes	Yes, Teaching Fellow or Clinical Specialist	As required, electronic communication weekly otherwise	Sometimes
Organisation of PSTs—individual, pair, group teaching	Pairs of PSTs work with 6–8 primary students	Group of 5 PSTs work in each classroom	Individual with a whole class	Individual with a whole class	Pair with a whole class
Classroom teacher involved	No	Informally	Yes, mentor for placement	Yes, work collaboratively to plan	Informally
Meeting between classroom teacher & PST	No	Debriefing	Placement	Yes, initial group meeting for all PSTs and teachers	Yes
PSTs report primary students' outcomes to the classroom teacher	Yes	No	Yes	No	Yes
Recognition for PST	Unit assessment, certificate and 3 field days	Unit assessment, certificate only	Unit assessment, placement days	Unit assessment	Unit assessment

A question in the pre-survey "*what do you hope to gain from this unit?*" was matched with a question in the post-survey "*what did you gain from this unit?*". In addition, the pre-survey had items regarding PSTs' science background and experiences of science on practicum which were not repeated in the post-survey and the post-survey probed PSTs' perceptions of the value and impact of the school-based experience.

Likert-style items, multiple choice and open response items were included in the surveys. Each Likert-style item was considered for its suitability for parametric analysis. Whilst Likert-style items are strictly ordinal and do not meet the assumptions associated with parametric analyses, Norman (2010) claimed that "many studies, dating back to the 1930s consistently show that parametric statistics are robust with respect to violations of these assumptions. Hence, parametric methods can be utilized without concern for 'getting the wrong answer'"(p. 625). Where pre-post items could be paired, box and whisker plots were generated to indicate whether *t* tests and calculation of effect sizes was appropriate. In other cases, boxplots and percentages of responses were evaluated to inform the selection of items for a parametric approach. Mindful of Grace-Martin's (2008) advice, a more stringent alpha level of 0.005 was used instead of the more usual 0.05 to mitigate against possible bias in the parameter estimates. Confidence items asked PSTs to rate their confidence to teach science in general and also to rate their confidence about a number of specific aspects related to teaching science: learn science content, undertake and supervise experiments, plan science lessons, create engaging classroom environment, manage behaviour of a group of students, undertake critical reflection on their own science teaching, establish and build on students' science understandings and be excited about the science they taught. Other items probed their opinions related to practicum experiences and motivation to teach science. Feedback on the school-based approach to science education was also sought.

Participants

This paper reports on the survey data from 108 PSTs completing the pre-survey and 107 PSTs completing the post-survey including 30 PSTs who completed both the pre- and the post-surveys, with pairing established by matching identification codes. For the purpose of reporting on the data in this paper, the PSTs will be referred to by pseudonyms. Table 2 shows the age and gender distribution of this group of PSTs.

Table 2 Distribution of PSTs who completed the surveys

Gender	Pre	Post	University	Pre	Post	Age	Pre	Post
Male	11%	8%	ACU	18%	12%	18–20	13%	14%
Female	89%	92%	Deakin	32%	39%	21–25	48%	59%
			RMIT	20%	43%	26–30	19%	12%
			Melb	30%	6%	31–35	5%	2%
						36–40	4%	5%
						41–45	6%	4%
						46+	6%	4%

Results

This section reports on the analysis of the quantitative and qualitative data obtained from the surveys. Comparisons are given where matching of items was possible. Pairing of responses for the 30 possible pairs was achieved using the PSTs' unique identifiers as they were not required to give their names when completing the surveys. This section begins with the results of items from the pre-survey which did not appear in the post-survey, followed by an analysis of the matched items and finally an analysis of responses to items in the post-survey which did not appear in the pre-survey.

Pre-Survey only Items

In the pre-survey, PSTs were asked about the science they had studied at school and university and this contributes to our description of the participants. They were also asked whether they had seen or experienced science teaching whilst on practicum. These items were not matched with items in the post-survey.

Comments Relating to Science on Practicum

Contrary to the literature cited above, science did appear to be observed and taught on practicum. About half of the PSTs (49 of 108) had seen science taught on practicum, and 62 PSTs had the opportunity to teach it. Various comments reflect the range of the place of science in schools as seen on practicum—from apparently no regular science at the school through to integration with other curriculum areas.

Rowena: the school has no formal science teaching program.

Sharyn: science lessons taught by specialist Science teachers.

Hayley: weekly experiments conducted by a parent with a scientific background.

Mai: [I saw] students growing plants in the class and learning about the scientific process, [but] prior to this unit, I have not taught a science based activity in schools.

Sam: integrated unit on weather and sustainability.

Matched Items

Several items in the surveys were able to be compared. Likert-style items regarding confidence and motivation to teach science and the PSTs perceptions of the importance of science were included in both surveys. In the pre-survey, PSTs were asked *What do you expect to gain from this science unit?* This was matched with a question in the post-survey: *What did you gain from this science unit?* These common items enabled a comparison of responses before and after the experience of engagement in the school-based units.

Motivation

In the post-survey, PSTs were asked to respond on a ten-point scale (1 = not at all, 10 = totally) to four items probing their motivations to teach science:

- How important is science in primary school curriculum?
- To what extent does your interest in science motivate you to learn and teach science?

- To what extent does your commitment to your students motivate you to learn and teach science?
- To what extent does your interest in science motivate you to learn and teach science?

Figures 1, 2, 3 and 4 show boxplots of the responses to these items on the pre-survey (left) and the post-survey (right). All items are rated highly in both surveys, with very little difference between the pre-survey responses and the post-survey responses (see Figs. 1, 2, 3 and 4). Consequently, no parametric analyses were conducted on these items.

The wide spread of ratings for the item *To what extent does your interest in science motivate you to learn and teach science?* indicated by the interquartile range for this item suggests that there are differences in the motivating influence of interest in science. Closer examination of the data shows that ratings for this item range from 3 to 10, confirming that there is wide variation in PSTs' interest in science. The interquartile range of the matching item in the post-test is much smaller, indicating that the spread of ratings was markedly reduced by the time of the post-survey. In addition, it is particularly interesting to note the very high rating of the third item in this group. Although there appears to be no change in PSTs' commitment to their students, possibly due to the wide range of responses indicated by the interquartile range for the item on pre-survey, this is clearly very important to these PSTs and may be a factor which can be leveraged to further enhance the learning of primary science education.

Confidence

A strong theme in the literature is teachers' and PSTs' lack of confidence to teach science. Consequently, the pre- and post-surveys had matching Likert-style items about confidence. In both surveys PSTs were asked to respond on a five-point scale (1 = very under confident, 5 = very confident) to eight items asking "*How confident do you feel about doing the following?*"

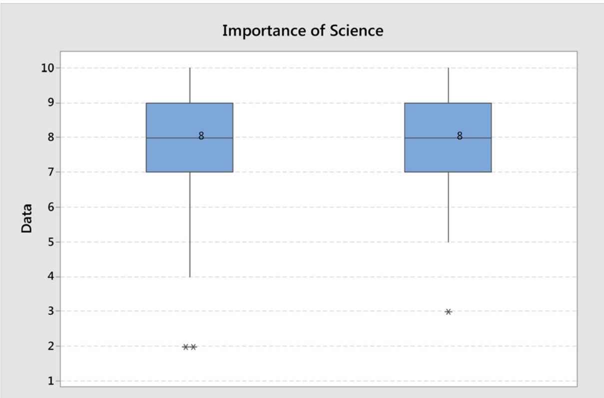


Fig. 1 Boxplot of responses to the question "How important is science in primary school curriculum?"

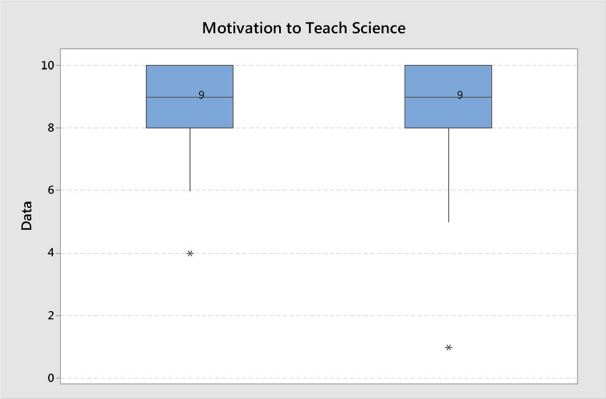


Fig. 2 Boxplot of responses to the question "To what extent does your interest in science motivate you to learn and teach science?"

- Learning science content
- Undertaking and supervise experiments with students
- Planning science lessons
- Creating an engaging classroom environment
- Managing the behaviour of a group of students
- Undertaking critical reflection on my science teaching
- Establishing and building on students' science understandings
- Being excited about the science I am teaching

Boxplots were undertaken of the responses to these items to indicate their suitability for parametric analysis. Figures 5, 6, 7, 8, 9 and 10 show boxplots with a sufficiently strong difference between the pre- and post-surveys, supporting the decision to employ parametric analysis. Figures 6 and 8 are particularly interesting as they show a polarised response to those items on the pre-survey with a strong shift to increased confidence on

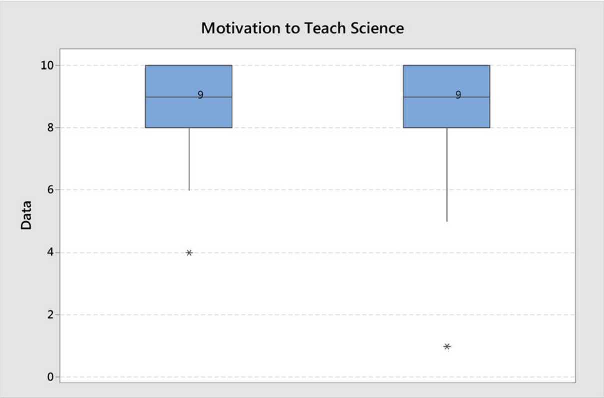
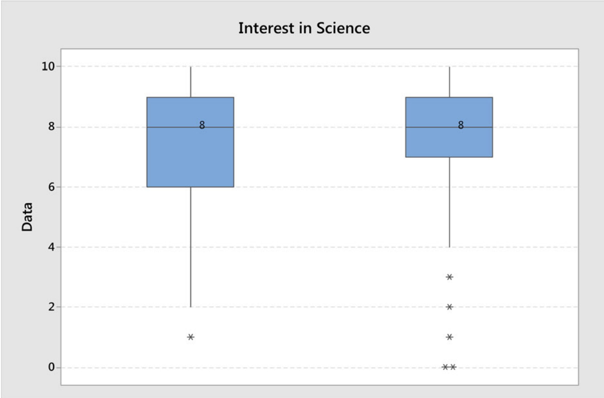


Fig. 3 Boxplot of responses to the question "To what extent does your commitment to your students motivate you to learn and teach science?"

Fig. 4 Boxplot of responses to the question "To what extent does your interest in science motivate you to learn and teach science?"



the post-survey. Conversely, Fig. 10 shows a shift to a higher level of confidence by a significant number of PSTs.

We performed *t* tests on these items and calculated the effect size. Table 3 shows the means and standard deviations for each item for both the pre- and post-surveys and the associated effect sizes, along with the *p* values resulting from the *t* tests. The effect size has been included to support and complement the *p* value resulting from the *t* test. Cohen's D effect sizes (Cohen 1988) were calculated to gauge the degree of effectiveness of the school-based experience on changing PSTs' confidence to teach science. Cohen (1988) categorised effect sizes as "small, $d = 0.2$", "medium, $d = 0.5$" and "large, $d = 0.8$" (p. 25).

However, when the more stringent alpha level of 0.005 was applied, the *p* value (0.03) for "Confidence to undertake critical reflection on their own science teaching" was deemed too weak to be confident that there is a significant difference between the responses on the surveys for this item. *P* values less than 0.005 indicate aspects of science teaching that resulted in statistically significant gains in confidence, that is *learn science content*, *undertake and supervise experiments*, *plan science lessons*, *create engaging classroom environment*, and *establish and build on students' science*

Fig. 5 Boxplot of responses to "*Learning science content*"

Fig. 6 Boxplot of responses to "Undertaking and supervise experiments with students"

understandings. The effect sizes for these aspects indicate a small to medium degree of effectiveness of the school-based experience on increasing PSTs' confidence to teach science. Only for one aspect, that is *plan science lessons*, did the effect size indicate a *large* degree of effectiveness.

When asked to respond on a ten-point scale (1 = not at all, 10 = totally) the broad question "How confident are you to teach science?", the corresponding boxplots suggest that the PSTs' responses on the pre-survey (left) were sufficiently different from that on the post-survey (right) (see Fig. 11) to benefit from analysing this item with a *t* test ($p = 0.0001$) and effect size calculation (0.55). These results indicate that there is a significant difference from the pre-survey to the post-survey in the PSTs' responses to this item.

Changes in Perspectives: a Result of the School-Based Experience

Features of the school-based science program that may have contributed to these significant gains in confidence can be deduced from the 30 paired responses to the matched open-response items: *What do you expect to gain from this science unit?*;

Fig. 7 Boxplot of responses to "*Planning science lessons*"

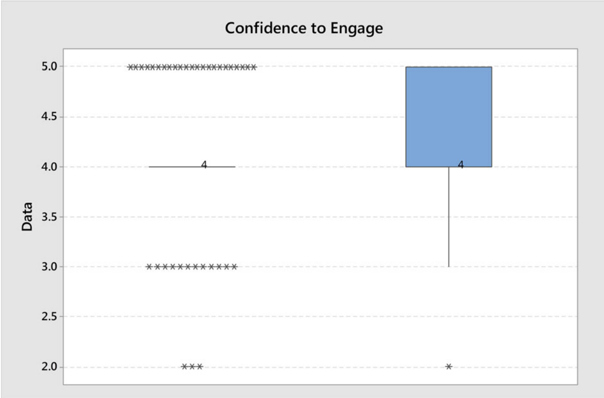


Fig. 8 Boxplot of responses to "Creating an engaging classroom environment"

What did you gain from this science unit? Some of the post-survey responses were simply an expression of meeting the expected gains. However, in addition, new to the post responses were a range of ideas that can only emerge through experience of teaching science in authentic settings, where science teaching in the context of the school is allowed for and enabled. When reviewing the data from the matched items, some differences were seen in the PSTs' expectations of the program. Some PSTs with limited science background tended to focus on gaining content knowledge whereas other PSTs with more depth in their science background expressed the expectation that they would gain further knowledge and experience in teaching science. In the post-survey, several PSTs commented on the opportunity to implement theory in practice. For example,

> Tom: It is the practical aspect of it that often trips people up, I can learn about how to teach plenty but doing it is another matter, particularly in Science as it's not often taught on placement and often gets overlooked.
> Suzie: It provides you with a chance to link theory to practice.

Fig. 9 Boxplot of responses to "Undertaking critical reflection on my science teaching"

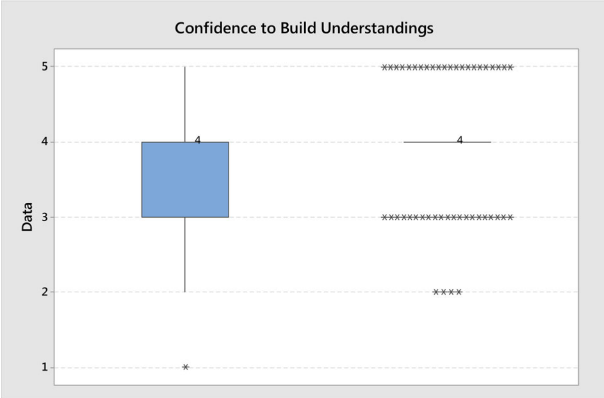


Fig. 10 Boxplot of responses to "Establishing and building on students' science understandings"

Jane: For the unit content to have any relevance, we need to be in schools, applying what we are learning in lectures, tutorials and workshops.

For the 30 PSTs completing both surveys a comparison of their responses in the pre-survey with the matched item in the post-survey indicates their awareness of the value of the school-based experience for improving their ability to teach science. From these paired responses, it appears that the PSTs' expectations of the program had been met.

Bree (Pre): [I hope to gain] a better understanding of general science. Learn the topics I didn't properly learn in high school to a quality level so that I can teach it to my students confidently.

Bree (Post): Participating [in teaching science] at this school has helped me become more confident.

Sally (Pre): I hope to gain a broader understanding of the science curriculum as well as how to teach it in a primary school setting.

Sally (Post): A better understanding of how to teach primary science.

Wendy (Pre): [I hope to gain] practice with teaching science.

Wendy (Post): This was the only opportunity I have had to teach not only a sequence, but also Science.

Table 3 Changes in PSTs' confidence

Confidence to: (5-point scale) 1 = very under confident 5 = very confident	Mean		Standard deviation		*p* value	Effect size
	Pre	Post	Pre	Post		
Learn science content	3.78	4.13	0.84	0.69	0.001	0.45
Undertake & supervise experiments	3.85	4.31	0.73	0.63	<0.001	0.69
Plan science lessons	3.47	4.18	0.92	0.70	<0.001	0.87
Create engaging classroom environment	4.05	4.29	0.67	0.65	0.003	0.36
Undertake critical reflection on their own science teaching	3.92	4.15	0.79	0.76	0.03	0.30
Establish and build on students' science understandings	3.48	3.93	0.82	0.75	<0.001	0.58

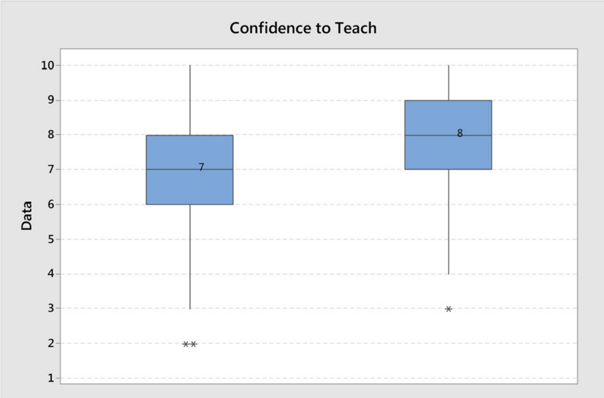


Fig. 11 Boxplot of responses to "How confident are you to teach science?"

Other key ideas emerged from the paired responses: reality of teaching, knowledge of learners, teacher identity and teacher reflection.

Shifts in PST thinking about the reality of teaching: where there was expression of the enormity and complexity of the task of teaching a sequence, or in using the strategies and approaches they are being taught by their teacher educator to use, and an understanding of the value and positioning of science in schools and that it should be valued but often is not. Anne expressed a change in focus from single activities to teaching a sequence.

> Anne (Pre): I hope to gain an insight into what kind of activities I can teach children at primary level. What to teach and how to teach.
> Anne (Post): Teaching a sequence of lessons to the same children for seven weeks was a wonderful experience. We got to know the children and even anticipated what each child's answers would be. I gained more insight into a classroom teaching and learning than the two weeks of rounds.

Kylie and Emma have expressed a shift in thinking about learning in a *philosophical* way to becoming aware of the *complexity of teaching science*:

> Kylie (Pre): instilling a lifelong love for science in my students.
> Kylie (Post): an understanding of all the elements that need to be considered when undergoing [sic] hands-on experiments with students- appropriate planning, explicit instructions that are constantly re-iterated, ensuring care and safety, demonstrating how to use any equipment, explaining how to predict and record, and keeping track of everything!
> Emma (Pre): Confidence planning and teaching science. / FUN with science for my students!
> Emma (Post): Understanding of how difficult it can be to implement science in the classroom.

Shifts in PST thinking about their knowledge of learners through linking theory to practice: reflecting the children's responses to the science experience and the need to build ideas over time. Narelle expresses a shift from an emphasis on *science content and teaching it* to an emphasis on *bridging theory and practice*:

> Narelle (Pre): I hope to be able to understand how to teach science effectively and see what needs to be undertaken before teaching a science unit - particularly if I don't understand it properly.

Narelle (Post): Confidence. Actual experience to go with theory and knowledge I have learnt.

Shifts in PST thinking about their teacher identity: an increased efficacy as a teacher of students and/or science. This pair of quotes indicates a shift from thinking about *themselves* to thinking about *the students they teach* indicating a shift in identity:

Betty (Pre): Experience and building confidence in teaching science concepts.
Betty (Post): Improving my perspective of the abilities and interests of specific year levels. Observing the realities of inquiry learning.
Martin (Pre): [I hope to gain] More skills in the teaching of science.
Martin (Post): I realised how hard it is, even with a small group, to teach to all levels of understanding.

Shifts in PST thinking about teacher reflection: the importance of ongoing reflection for lesson and unit implementation and understanding learners; that reflection is needed for improvement in teaching knowledge and practice and that reflection is a mechanism for change. In the pre-survey, Marion focused on her science content knowledge whilst in the post-survey, her response suggests a shift in thinking to an awareness of the importance of reflection in designing a sequence of lessons. For Mary, her initial concern was being able to find time for science but in the post-survey, her focus had shifted to acknowledging the role of reflection in becoming a better teacher.

Marion (Pre): Deeper understanding of scientific concepts
Marion (Post): Reflecting on teaching/ designing a teaching sequence
Mary (Pre): How to integrate science into an already crowded curriculum.
Mary (Post): Putting into practice the lesson plans that you devise is an effective way of learning. You can reflect on your own teaching and make notes of what worked and what didn't for future.

Post-Survey-Only Items

These are items appearing only in the post-survey and focused on the PSTs' experiences of the school-based science education program, such as their perceptions regarding the effectiveness of their teaching and feedback on the experience.

Effectiveness of Science Teaching

PSTs reported increased confidence to teach science (see Table 3) and whilst it is only their self-reported opinion, it appears that they believed their teaching was effective, for example:

Jenny: My students loved the science lessons and doing the experiments. They also learnt important science concepts whilst having fun at the same time.
Melissa: by asking them to reflect on their learning we could gauge what each student had learnt.
Debra: the students learned something from the unit

For the question "*To what extent do you feel that you had a positive impact on students' learning?*", some responses appear to reflect some uncertainty about the students' learning, whereas other responses from PSTs who had undertaken extra tertiary science indicate an emphasis on the engagement of the students.

> Mai: I believe students' learning was good, definitely could have been greater though, with proper support from qualified teachers/tutors for direction. (Year 11 science)
> Dianna: The students learned something from the unit. (Year 12 science)
> Mary: Our students seemed engaged with each lesson and were always eager to tell us what discoveries they had made during the week relating to our topic. (Additional Tertiary science)

The following examples emphasise the evidence used by PSTs to determine student interest and excitement about learning science. In terms of impact, it is difficult to ascertain if the cause is *because* of the PSTs' teaching; however, these PSTs demonstrate their awareness of students' engagement:

> Anne: When we arrived every Monday they rushed to our table and wanted to show us their results. Seeing their faces was the best experience.
> Mai: Students were always very excited to come to our class and were always engaged in learning activities.
> Mary: The students would bring in books and tell us about YouTube clips and TV programs about our topic. Some even wrote on feedback sheets that they want to be a scientist when they grow up.

When responding to "*To what extent has your approach to science teaching become more positive?*", some PSTs expressed the view that their existing positive attitudes to science had not changed, whilst others commented on aspects of science teaching gained from engagement in the school-based science unit:

> Anne: I have always loved science and had a positive attitude before I started.
> Wendy: I feel that the emphasis on engaging, hands on science activities supported my existing attitude. However seeing different scientific areas modelled by my peers has really boosted my confidence in my ability with all science areas (even ones I haven't encountered yet).

Jenny commented on changes in confidence rather than changes in approach. For example:

> Jenny: I feel more confident in teaching science, because I've had the chance to plan and teach a whole science sequence.

Feedback on School-Based Experience

PSTs emphasised the value of spending time working with students in schools, commenting on their increased confidence as teachers. For example:

> Jenny: Being able to plan and implement a whole science sequence in a real classroom environment has helped me become a confident science teacher. I now feel confident to teach science to students and feel I have the knowledge and resources to implement science into the classroom.

In response to the question "*Which aspects of the school experience were most valuable?*" several main themes emerged. The most frequent aspect mentioned were the advantages related to working with students. For example:

Bree: Gaining the hands on experience and working with actual children, is the best educational tool for learning how to teach effectively.

Another frequently mentioned advantage was the opportunity to plan and implement a lesson sequence over an extended period of time.

Dianna: Being able to teach a complete unit and assess the students at the end of it.
Mary: [Being with] the same group of students each week is great in being able to build a rapport with the students.

Other advantages referred to team teaching; and opportunity to trial approaches.

Gayle: Team teaching with a fellow classmate made the experience more enriching as we were able to bounce ideas off one another and support each other throughout the planning and teaching of the sequence.
Mary: Visit all five stages of the 5E's model and really absorb how effective this model is for teaching science.

Another advantage was mentioned by Paul, in response to the question "*What did you gain from this school experience?*", who found that the opportunities to reflect on his teaching were formative in his teacher development. Freda highlighted that her reflection on practice was also informed by feedback from the classroom teacher.

Paul: Through reflection I was able to see many areas in which I need to improve my practice.
Freda: Great positive feedback and reflection on lesson from my classroom teacher. Pointers included as to improvements that could be made.

Responses to the question "*To what extent has the school experience helped you be more positive in the way you see yourself as a teacher?*" indicate that the school-based experience of science teaching also influenced PSTs perceptions of themselves as teachers. For example:

Mai: Having the ability to spend more time in a classroom has definitely helped me increase my confidence as a teacher. Having small groups definitely makes it easier to keep students engaged and on task. This is building pre-service teachers' ability to maintain the focus and attention of whole class groups.

Two items in the post-survey related to the PSTs' perceptions of support provided. Some responses to these items emphasised the support given by teacher educators, peers and classroom teachers, whilst others referred to the support provided by resources.

Bree: [The supports that made the experience successful were] teacher [tutor] and peer support. Also the supervising classroom teacher was really excited to have us in her classroom.
Martin: I liked the class [tutorial] sharing of teaching ideas. We used one of the Primary Connections units on which to base our teaching.
Anne: The internet, teacherspayteachers [was a] wonderful resource and Skamp [Teaching Primary Science Constructively] and Primary Science Education Ideas book [Ideas for Teaching Science: Years P–8]. Both books had great questions to ask children and reasons why we ask them.

Some PSTs who had not studied any science at year 12 level felt that they required more support than was supplied:

Mai: Having tutor support or primary teacher feedback throughout the sequence would have made the experience more beneficial. We did not receive any feedback except from [primary] students and did not receive any ideas to improve or better our teaching strategies, or what worked well and to keep that aspect continuing.
Sally: The chance to submit planning earlier and actually get feedback on it. The chance to learn a bit more before having to go straight into planning and teaching the sequence.
Gayle: More support and flexibility was needed from the tutor. I felt rather judged from my tutor due to my lack of science knowledge. Support from the school teachers/aides would have helped in gaining a better understanding into some students needs and learning abilities.

Summary of Results

Key aspects of the school-based programs of science education are highlighted by the quotes above. Some PSTs expressed a growing awareness of the enormity and complexity of the task of teaching a science sequence or in using the strategies and approaches they are being taught by their teacher educator to use, coming to an understanding of the value and positioning of science in schools and that it should be valued but often is not. Others reflected on the students' responses to the science experience and the need to build ideas over time—acknowledging the importance of ongoing reflection for lesson and unit implementation and understanding learners — and that reflection is needed for improvement in teaching knowledge and practice. Also expressed were comments regarding their increased efficacy as a teacher of students especially in regard to teaching science.

These key aspects included learning through practice, their commitment to the students they teach, the opportunity to bridge theory and practice and an appreciation of the complexity of teaching science. Whilst small, there were some indications that previous science background had a slight influence on the level of support needed from the teacher educator; it appeared that the less experienced PSTs required greater support and exhibited less confidence in their ability to positively impact students' learning. These are only indications, and further examination of this aspect is needed to inform the design of school-based programs for science education. The following response sums up the aspects of the experience most PSTs valued.

Wendy: Having the freedom to plan a sequence of our choice, and building upon understanding (and clarifying misunderstanding) over a period of time. This was a great experience and I wish that similar subjects were run within other curriculum areas! It was great to go into schools with a specific subject to focus on. The professional experience rounds do not guarantee actual planning and teaching in each domain, and this specific experience allowed full focus on the subject matter. Unlike rounds, this experience focused much more on teaching content rather than classroom management, which is greatly beneficial.

Significant gains in confidence are evident in the survey data for learn science content, undertake and supervise experiments, plan science lessons, create engaging classroom environment, manage behaviour of a group of children, establish and build on children's science understandings and teach science. The effect sizes for these aspects indicate that the school-based program of science education was moderately effective in raising the confidence of PSTs to teach science.

Discussion

The STEPS school-based approach to pre-service science teacher education reflects the fundamental principles of connecting educational theory and classroom practice, building partnerships between universities and schools and reflecting on practice as key foci when learning to teach science. These principles represent a significant and innovative approach to teacher education that addresses concerns about the lack of coordination of theory and practice in teacher education courses and the need for better models of university-school-community relationships in teacher education (ACDE 2004). This approach, similar to Bottoms et al. (2015), signifies a significant curriculum renewal in science education, pointing the way forward for theory-practice coordination into teacher education in general. In addition, TEMAG (2015) recently advocated increased use of cooperation between schools and initial teacher education providers. The results of this study show that concerns regarding traditional PST education can be overcome by a school-based approach built on the principles of the STEPS program. The PSTs' perceptions of the school-based experience and the actual lived experience contribute to their development as classroom-ready teachers as recommended in the Ministerial Issues paper (TEMAG 2015).

The data collected from PSTs involved in the STEPS program suggest that this school-based approach is successful in providing PSTs with opportunities to implement science education theory in real classroom contexts. Through these school-based experiences, the PSTs come to express a realisation of the challenges of teaching science and the many aspects needing attention which they may not experience within the usual practicum arrangements (Tytler 2007). Important in the success of the program is the support provided by teacher educators who advocate the development of conceptual understanding, hands-on activities and an inquiry approach (Hobbs et al. 2015). The presence of teacher educators working with PSTs in the school environment mitigates against the lack of opportunity for PSTs to experience supported science education on practicum (ASTA 2014).

The survey responses highlight important aspects of the STEPS program instrumental in effecting gains in confidence, such as planning, implementing and reflecting (Carr & Kemmis 1986) on a sequence of science lessons conducted in primary schools with small groups of students. The increase in confidence to "teach science" might be expected within a practice-based unit but only where planning, implementation and reflection were major components of a unit. This is consistent with Hoban's (2007) finding that opportunities to plan, implement and reflect assisted PSTs to understand science concepts on a deeper level. In the STEPS program, after each lesson with the students, PSTs' reflections were supported through teacher educator scaffolding and sharing with their peers. PSTs reflected on the effectiveness of the lesson and the student's learning and used this reflection to plan follow-up lessons. This cycle is important in enabling immediate and insightful reflection on practice (Carr & Kemmis 1986) and can only be achieved where real implementation of lessons is part of the learning process, thus differentiating these school-based approaches from traditional tutorial-bound approaches to science teacher education. Critical to the success of the STEPS program is access to primary school students. Experience working with primary school students may be achieved by bringing groups onto a university campus or by having one-off teaching events or science fairs (as reported in Kenny et al. 2016); however, the STEPS program enabled PSTs to work with primary school students over an extended period of time in the school environment. This extended time also providing opportunities for PSTs to engage in the plan, implement and reflect cycle on a weekly basis.

The data positively shows that the experience attends to some of the concerns raised in the literature about primary science teachers. In response to the low confidence of many primary teachers to teach science (Cooper, et al. 2012; Gess-Newsome & Lederman 2001), the data showed that PSTs valued the experience of teaching science in schools as part of their course resulting in increased confidence to teach science. In response to the low self-efficacy of many PSTs (Palmer 2006), the analysis of the qualitative data points to increased self-efficacy of PSTs. The significant gain in confidence to undertake and supervise experiments is especially important as experimental work can often seem daunting to a teacher due to the organisational requirements regarding space and resources and the potential for a disrupted classroom (Jones & Carter 2007; Kidman 2012). The gains in confidence in establishing and building on students' science understandings ($p = 0.001$) is not surprising as this is a strong focus of the school-based models in the STEPS project and stems from a constructivist background to science education common to the teacher educators involved in teaching primary science education (see for example the text Skamp & Preston (2015) for an analysis of constructivism in science education). In addition, it may be that this gain in confidence is a product of the experience involving authentic interaction with primary school students, with diagnostic assessment and elicitation techniques implemented with a conceptual focus on science learning experiences for students in primary schools. This is contrary to the common focus of science in the primary classroom on activity and engagement without commitment to conceptual development (Tytler 2007), so it is encouraging to see commitment to conceptual ideas in the qualitative data.

However, the data for this project does not show that self-efficacy as a PST is a predictor of the quality of the teacher as there are many factors that can determine the effectiveness of science programs in a school (Kenny 2009). Consequently, this is an area needing further study investigating the critical success factors for these kinds of partnership arrangements. Whilst it is important to raise the confidence of PSTs to teach science and improve their attitudes to science during their course, this does not automatically translate to confident early-career teachers. Many factors are at play when graduate teachers begin to teach and gains in confidence encouraged at university are an important step in assisting them to approach the teaching of science more positively than they might otherwise. When PSTs have a positive experience of teaching science in a supported context, they can be convinced of the power of science as a context for learning so they begin to see science through the students' eyes. When supported, there is opportunity for reflection on successes and failures that might arise thus responding to the complex nature of teaching science allowing, and indeed perhaps encouraging, PSTs to take risks in their own learning. Whilst it was difficult in this project to get a sense of identity shifts, there are some indications of PSTs legitimately engaging with an identity of a teacher who could teach science.

Conclusion

The school-based experience of the STEPS program was shown to authentically engage these PSTs with the teaching of science whilst being supported by their teacher educators. The data from these surveys indicate that quality and effective science teacher education can be achieved when PSTs are given the opportunity to take advantage of a partnership between university and schools which results in authentic interaction with students in schools for the purpose of bridging the theory-practice divide. This approach facilitates authentic experiences for PSTs whilst allowing pedagogical and learning theory (for example, inquiry, constructivist theory, 5E Instructional model, diagnostic, formative and summative assessment, representations), as well as science content and pedagogy (for example, content knowledge and strategies for teaching chemical and physical change) to be applied to teaching. In this way, PSTs' practice is informed by pedagogical and learning theories supplied by teacher educators who play an active role in supporting the PSTs in schools. An important feature of the STEPS program is PSTs' involvement in planning, implementing and assessing a learning sequence in science. The implementation of the sequence over time, with adjustments made through reflection on the students' learning, adds to the PSTs' development and identity as a teacher (STEPS 2014).

This approach of integrating the coursework with practical experience differs to Preston et al.'s (2006, 2007) approach (on placement compared to during coursework in our approach); whilst both approaches required PSTs to complete a science teaching sequence with students, our approach enabled the teacher educator to support reflection and discussion around relevant theory *at the time of the teaching experience* assisting PSTs in making direct links between theory and practice but also helping PSTs to understand how planning and teaching can be informed by the theories often presented only at university. The Ministerial Issues paper by TEMAG (2014) asks the question "How can partnerships between teacher education providers and schools be strengthened to make teacher education more effective?" We argue that by using such partnerships as part of coursework, with on-demand and on-site support from the teacher educator, it is possible to give PSTs an opportunity to improve their confidence, ability and willingness to teach quality science lessons in readiness for when they enter the profession.

Compliance with Ethical Standards

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Appendix

School-Based Teaching – Pre-Survey

Q1 Provide a "Unique Identifier". The Unique Identifier should consist of 9 digits: "first 3 letters of your mother's maiden name" (3 letters, eg. LID for Lidstone) "your birth month" (2 numbers, eg. 07 for July) "your birth year" (4 numbers, eg. 1946). Unique identifier would be LID071946. Please remember this identifier for the post-survey.

Q2 What is your Institution?

Q3 Which campus?

Q4 What school do you attend for your school experience for this unit? (Please specify)

Q5 What degree are you studying?

Q6 Are you studying full-time or part-time?

Q7 Are you Male or Female

Q8 What is your age (years)? 18-20, 21-25, 26-30, 31-35, 36-40, 41-45, 46+

Q9 Which of the following science subjects did you complete in secondary school?

	General science (1)	Chemistry (2)	Physics (3)	Biology (4)	Environmental Science (5)
Year 9	❑	❑	❑	❑	❑
Year 10	❑	❑	❑	❑	❑
Year 11	❑	❑	❑	❑	❑
Year 12	❑	❑	❑	❑	❑

Q10 What science units have you studied at university?

Q11 Have you seen science taught on your placement?

- ❑ Yes, a unit with a science focus (Please specify) ____________________
- ❑ Yes, individual activities (Please specify) ____________________
- ❑ No (Please explain) ____________________

Q12 Have you taught science on your placement?

- ❍ Yes, individual activity/activities (Please explain) ____________________
- ❍ Yes, a sequence of science lessons (Please explain) ____________________
- ❍ No (Please explain) ____________________

Q13 How confident do you feel about doing the following?

	Very under confident (1)	Under confident (2)	Neither under confident nor confident (3)	Confident (4)	Very confident (5)
Learning science content	❍	❍	❍	❍	❍
Undertaking and supervise experiments with children	❍	❍	❍	❍	❍
Planning science lessons	❍	❍	❍	❍	❍
Creating an engaging classroom environment	❍	❍	❍	❍	❍

Managing the behaviour of a group of children	❍	❍	❍	❍	❍
Undertaking critical reflection on my science teaching	❍	❍	❍	❍	❍
Establishing and building on students' science understandings	❍	❍	❍	❍	❍
Being excited about the science I am teaching	❍	❍	❍	❍	❍

Q14 What do you hope to gain from this unit? Please describe.

Q15 When you are a teacher...

	frequency				
	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	All the time (5)
How often do you EXPECT to teach science?	❍	❍	❍	❍	❍
How often do you HOPE to teach science?	❍	❍	❍	❍	❍

Please explain

Q16 On a scale of 1 to 10 rate yourself against the following (1= not at all, 10 = totally):

______ How important is science in primary school curriculum?

______ How confident are you to teach science?

______ To what extent does your commitment to your students motivate you to learn and teach science?

______ To what extent does your interest in science motivate you to learn and teach science?

School-Based Teaching – Post Survey

Q1 Provide a "Unique Identifier". The Unique Identifier should consist of 9 digits: “first 3 letters of your mother’s maiden name” (3 letters, eg. LID for Lidstone) “your birth month” (2 numbers, eg. 07 for July) “your birth year” (4 numbers, eg. 1946). Unique identifier would be LID071946. This should be the same as the identifier used in the pre-survey (if completed).

Q2 What is your Institution?

Q3 Which campus?

Q4 What school do you attend for your school-based science unit or course? (Please specify)

Q5 What degree are you studying?

Q6 Are you studying full-time or part-time?

Q7 Are you Male or Female?

Q8 What is your age (years)? 18-20, 21-25, 26-30, 31-35, 36-40, 41-45, 46+

Q9 How confident do you feel about doing the following?

	Very under confident (1)	Under confident (2)	Neither under confident nor confident (3)	Confident (4)	Very confident (5)

Learning science content	❍	❍	❍	❍	❍
Undertaking and supervise experiments with children	❍	❍	❍	❍	❍
Planning science lessons	❍	❍	❍	❍	❍
Creating an engaging classroom environment	❍	❍	❍	❍	❍
Managing the behaviour of a group of children	❍	❍	❍	❍	❍
Undertaking critical reflection on my science teaching	❍	❍	❍	❍	❍
Establishing and building on students' science understandings	❍	❍	❍	❍	❍
Being excited about the science I am teaching	❍	❍	❍	❍	❍

Q10 What did you gain from this school experience? Please describe.

Q11 Which aspects of the school experience were most valuable?

Q12 What types of supports made the experience successful?

Q13 What other types of supports would have been helpful?

Q14 Please respond to the following questions...

	Response			
	None (1)	Minimal (2)	Average (3)	High (4)
To what extent do you think school-based experiences are important within discipline curriculum units at university? (e.g. science, maths, literacy)	❍	❍	❍	❍
To what extent do you feel that you had a positive impact on students' learning?	❍	❍	❍	❍
To what extent do you feel you had a positive impact on students' attitudes towards science?	❍	❍	❍	❍
To what extent has your approach to science teaching become more positive?	❍	❍	❍	❍
To what extent has the school experience helped you be more positive in the way you see yourself as a teacher?	❍	❍	❍	❍

Please explain

Q15 When you are a teacher...

	frequency				
	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	All the time (5)
How often do you EXPECT to	❍	❍	❍	❍	❍

teach science? How often do you HOPE to teach science?	❍	❍	❍	❍	❍

Please explain

Q16 On a scale of 1 to 10 rate yourself against the following (1= not at all, 10 = totally):

______ How important is science in primary school curriculum?

______ How confident are you to teach science?

______ To what extent does your commitment to your students motivate you to learn and teach science?

______ To what extent does your interest in science motivate you to learn and teach science?

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