Primary science for a new age: A mixed methods, multi-stage investigation of innovative practices in preservice primary science education

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Bachelor of Education (Primary) (Honours) (First Class)

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December 2016
Certificate of Authorship

I hereby declare that this submission is my own work and to the best of my knowledge and belief, understand that it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgement is made in the thesis (or dissertation, as appropriate). Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged.

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Date: 20/12/2016
Acknowledgements

My journey to completing this doctorate has been long, arduous, but very rewarding. Without the support of those close to me, I would not have been able to finish. I would like to acknowledge those contributed along the way.

I thank my supervisors, Dr Lena Danaia and Professor David McKinnon, for their unwavering supporting and guidance through the PhD process. Both of you have served as role models for what I would like to accomplish one day.

I thank my lovely wife, Hannah, who treated me with love and kindness as I strived to complete this undertaking. You believed in me when I did not believe in myself and for that, I can never repay you.

I thank my family, Mum, Dad, Cameron and Mahalia, for your support, patience and understanding. Mum, you were always there to help me when I struggled. Dad, you reminded me (ever so gently) that there is still a world beyond this PhD.

I thank the staff who made CSU a friendly, supportive and welcoming place.
Abstract

In an era where scientific literacy is a clear necessity, Australia’s science education system is mired by intergenerational disengagement and poor outcomes. Negative perceptions of science and limited scientific literacy in childhood often persist into adulthood. As many stakeholders, including teachers and students, are influenced by their own inadequate science education experiences, this cycle is challenging to break. The research presented in this dissertation focuses on preservice primary teachers due to their foundational position, accessibility and potential to enact long-term changes in science education. This dissertation aims to first establish a broader context of science research; prior to investigating the science teaching efficacy beliefs and science perceptions of pre-service primary teachers enrolled in two complex, innovative science courses. Furthermore, the graduate transition is addressed as the participants’ inservice science teaching efficacy beliefs and reported science practices are explored.

The research was conducted over nine years (2007-2015) and been presented across six publications. The first publication presents a meta-analysis of research which utilised the Science Teaching Efficacy Belief Instruments (STEBI-A/B). The second publication describes two complex, innovative science courses (SC108 and SC308). The third publication presents a four year investigation of the science teaching efficacy beliefs and experiences of a single cohort as they completed a science program (SC108 and SC308) and proceeded to graduation. The fourth publication reports on STEBI-B data collected from 877 preservice primary teachers who completed the two course science program. The fifth publication investigates the science teaching efficacy beliefs and reported science teaching practices of the participants.
after they had graduated to become inservice teachers. The final publication investigates the transition of a science course (SC308) from a face-to-face mode of delivery to an online mode of delivery.

The first publication showed that there is considerable methodological variety in terms of how the STEBI instruments have been used since original publication. Unsurprisingly, student-centred approaches to tertiary education and professional development produce the strongest growth in preservice and inservice teachers’ science teaching efficacy beliefs. Results from the remaining publications suggest that participation in the science program (SC108 and SC308) covaried with statistically significant increases to preservice primary teachers’ science teaching efficacy beliefs. The STEB increases remained durable in the absence of treatment at both the graduate and undergraduate levels. As early career teachers, the interviewees displayed a willingness to use engaging, student-centred approaches to science teaching despite hindering influences within their school contexts. Evidence presented in the final publication shows that the SC308 course design can be transitioned successfully, in terms of participant STEB growth and engagement levels, to an online mode of delivery. The dissertation ends with a discussion and conclusion section which outlines the relevance of the research, answers the research questions and discusses limitations, directions for future research and implications for practice.
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Certification from Supervisor

I, Doctor Lena Danaia, certify that the doctoral research entitled “Primary science for a new age: A mixed methods, multi-stage investigation of innovative practices in preservice primary science education” is in a form ready for examination for the degree of Doctor of Philosophy.

Doctor Lena Danaia

Date

21/12/2016
Certification from Co-Supervisor

I, Professor David McKinnon, certify that the doctoral research entitled “Primary science for a new age: A mixed methods, multi-stage investigation of innovative practices in preservice primary science education” is in a form ready for examination for the degree of Doctor of Philosophy.

[Signature]
David H. McKinnon

Professor David McKinnon

Date
21/12/2016
Ethical Approval

Ethical approval (see appendix 1, p.376) for the research contained in this doctorate was obtained from the Charles Sturt University Human Research Ethics Committee (2006/122 &300/2014/36). Participants received information sheets (see appendix 2, p.381) and consent forms (see appendix 3, p.385).
Statements from Co-Authors: Confirming the Authorship Contribution of the PhD Candidate

Publication One

As author of the paper entitled “The Science Teaching Efficacy Belief Instruments (STEBI A and B): A comprehensive review of methods and findings from 25 years of science education research”, I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

21/12/2016

James Deehan

Date
Publication Two

As author of the paper entitled “The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model”, I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

David H McKinnon 21/12/2016

Lena Danaia 21/12/2016

James Deehan 21/12/2016
Publication Three

As author of the paper entitled “A Longitudinal Investigation of the Science Teaching Efficacy Beliefs and Science Experiences of a Cohort of Preservice Primary Teachers”, I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

21/12/2016
James Deehan
Date

21/12/2016
Lena Danaia
Date

21/12/2016
David H McKinnon
Date
Publication Four

As author of the paper entitled “A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers”,

I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

21/12/2016

James Deehan

Date

21/12/2016

David H McKinnon

Date

21/12/2016

David McKinnon

Date
Publication Five

As author of the paper entitled “From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university”, I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

21/12/2016

James Deehan

Date

21/12/2016

Lena Danaia

Date

21/12/2016

David H McKinnon

Date
Publication Six

As author of the paper entitled “A model for the creation of cooperative e-learning spaces: Teaching early childhood and primary preservice teachers how to teach science”, I confirm that I made the following contributions:

- Conceptualisation of the paper
- Review and interpretation of the literature
- Writing, editing, and revision of the manuscript

Furthermore, I agree to the inclusion of the paper in this doctoral research submitted for examination.

21/12/2016

Lena Danaia

Date

21/12/2016

James Deehan

Date
Acronyms

ADT – Astronomy Diagnostic Test
CSU – Charles Sturt University
COGs – Connected Outcome Groups unit of work
CoRes – Content Representations
ES – Effect Size
GLM – General Linear Model
ICT – Information Communication Technology
IWB – Interactive Whiteboard
KLAs – Key Learning Areas
MANOVA – Multivariate Analysis of Variance
PaP-eRs – Professional and Pedagogical Experience Repertoire
PBL – Problem-Based Learning
PCK – Pedagogical Content Knowledge
PE – Professional Teaching Experience Placement
PISA – Performance in International Student Assessment
PSTE – Personal Science Teaching Efficacy
RFF – Relief from Face-to-Face (teaching)
SSSD – Small School Science Day
STEB – Science Teaching Efficacy Beliefs
STEBI-B – Science Teaching Efficacy Belief Instrument-B
STOE – Science Teaching Outcome Expectancy
SWOT – Strengths Weaknesses Opportunities Threats Analysis
TIMSS – Trends in International Mathematics and Science Study
UoW – Unit of Work
Glossary

Asynchronous – Delayed communication (e.g. emails, discussion forums).

Course (subject) – A single 12-week learning program delivered as part of a broader university degree. In this dissertation science courses (SC108 and SC308) within primary and early childhood university degrees

Inservice Primary (elementary) Teachers – Individuals who have completed their undergraduate studies are qualified to teach students from kindergarten (5 years old) through to year 6 (12 years old).

Preservice Primary Teachers – Individuals who are currently completing their studies in order to become qualified to teach students from kindergarten (5 years old) through to year 6 (12 years old).

PrimaryConnections – A federally endorsed Australian science program. Schools receive curriculum, resources and professional development to assist in the delivery of student centred, inquiry based primary science education.

SC108 – A pseudonym for a science content course delivered to students enrolled in their Bachelor of Education (Early Childhood and/or Primary) degrees during their first year of study. The course ran from 2005 through to 2013.

SC308 - A pseudonym for a science methods course delivered to students enrolled in their Bachelor of Education (Early Childhood and/or Primary) degrees during their second year of study. The course ran from 2005 through to 2014.

Synchronous – Instantaneous communication (e.g. phone, face-to-face discussion, skype).
A Note on the Structure of this PhD Dissertation

This PhD has been achieved through the publication of six separate papers that combine to create a deep, compelling research narrative. The dissertation has been designed to loosely resemble the structure of a traditional PhD dissertation. Table i shows the connections between the papers and the chapters that would typically be included in a traditional dissertation. While the language and formatting are consistent within the unpublished sections (abstract, introduction, review of literature, connective statements, discussion and conclusion), minor changes in formatting, language and referencing (e.g. “primary” is changed to “elementary” for international contexts).

Table i The relationship between the publications and a traditional PhD structure

<table>
<thead>
<tr>
<th>Publication</th>
<th>Title</th>
<th>Chapter Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Science Teaching Efficacy Belief Instruments (STEBI A and B): A comprehensive review of methods and findings from 25 years of science education research</td>
<td>Review of Literature</td>
</tr>
<tr>
<td>2</td>
<td>The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model</td>
<td>Context, Initial Results</td>
</tr>
<tr>
<td>3</td>
<td>A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers</td>
<td>Quantitative and Qualitative results (Preservice)</td>
</tr>
<tr>
<td>4</td>
<td>A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers</td>
<td>Quantitative Results (Preservice)</td>
</tr>
<tr>
<td>5</td>
<td>From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university</td>
<td>Quantitative and Qualitative Results (Inservice)</td>
</tr>
<tr>
<td>6</td>
<td>A model for the creation of cooperative e-learning spaces: Teaching early childhood and primary preservice teachers how to teach science</td>
<td>Quantitative and Qualitative Results (Transition to online learning)</td>
</tr>
</tbody>
</table>

Note: Methodologies are included separately within each paper
List of Appendices

Due to the choice made to present this dissertation through six publications, it became challenging to imbed the appendices within the body of the text. In anticipation of the needs of a prospective reader, the appendices are listed below.

Appendix 1: Ethics Documentation.

Appendix 2: Participant Information Sheet.

Appendix 3: Consent Form

Appendix 4: The STEBI-B

Appendix 5: The STEBI-A

Appendix 6: Interview Questions

Appendix 7: Publication Two Submission Proof

Appendix 8: Publication Three Submission Proof

Appendix 9: Publication Four Submission Proof

Appendix 10: Publication Five Submission Proof

Appendix 11: Important Constructs in Science Education Research
Introduction

Australian primary science education is in need of improvement. Primary students are becoming disengaged from science, showing inadequate levels of scientific literacy and are sliding down international rankings. Such problems may be cyclical as preservice and inservice teachers alike report poor science attitudes and low science teaching confidence, informed by detrimental experiences of science within their educational backgrounds. It is therefore unsurprising that science is often marginalised, with multiple studies indicating science is taught for 40-60 minutes per week in Australian primary schools. The limited science that is taught is often content heavy and teacher-centred.

Contrary to other areas of science education, preservice primary science programs have consistently reported positive outcomes, in terms of science teaching efficacy, attitudes towards science and content knowledge. An array of investigative, student centred approaches have been linked to these improved science outcomes for preservice primary teachers. Yet, evidence presented by large national studies and smaller contextually bound investigations almost uniformly indicates that the problems with science education at large remain relevant despite calls for and effort to make systemic change. This tension is crucial to the research presented in this dissertation. Furthermore, preservice and early career primary teachers represent an efficient group to target for change both due to the contextual factors (time, resources, location, etc.) and their increased potential to act as agents of change within primary science education for extended periods of time. Three aims underpin the research presented within this dissertation:
1) To determine how the science-teaching efficacy beliefs of both preservice and inservice primary teachers are represented within research literature and subsequently addressed through interventions.

2) To investigate the relationship between two complex, innovative and complementary science courses and the science teaching efficacy beliefs and science teaching perceptions of preservice primary teachers.

3) To investigate the science teaching efficacy beliefs and reported science teaching practices of former preservice primary teachers, who experienced the two complex, innovative and complementary science courses and who are now practicing inservice primary teachers.

To address these aims six separate, but related, research publications are presented across this dissertation. To enhance the research narrative a review of literature, a series of connective statements and a comprehensive discussion have been provided. The following paragraphs will briefly outline the content and purpose of each section comprising this doctoral dissertation.

The review of literature is a critical summary of the existing primary science education research literature. Key stakeholders are addressed, including students, inservice teachers, preservice teachers and universities. An argument is built for this dissertation’s focus on preservice and early career primary teachers. This chapter ends with the presentation of the research questions and aims. The following paragraph will familiarize the reader with each of the six research publications to be presented across this dissertation.

The first publication presents a comprehensive meta-analysis of 257 journal articles and dissertations which utilised the Science Teaching Efficacy Belief
Instruments (STEBI-A/B) in terms of research methods and findings reported. The second publication presents a robust description of two complex, innovative science courses (SC108 and SC308) and an emergent Interactive Educational Design Model (IEDM) supplemented by the findings of a long-term action research project. The third publication presents two complementary, Type II mixed methods case studies with multiple delay periods of testing that tracked the experiences and science teaching efficacy beliefs of a single cohort as they completed a science program (2 years) and proceeded to graduation (2 years). The fourth publication reports on STEBI-B data (quantitative) collected from 877 preservice teachers who completed the two course science program. A series of MANOVAs were conducted to assess participants’ science teaching efficacy beliefs both within and between the science courses. The fifth publication serves as a mixed-methods follow-up to earlier publications. The population of preservice teachers sampled in the fourth publication were targeted again as inservice teachers to determine if STEB gains remained durable and to openly explore their reported science teaching practice. The sixth, and final, publication investigates the transition of a science course (SC308) from a face-to-face mode of delivery to an online mode of delivery via a flexible, mixed methods action research approach. Connective statements are delivered between publications to recap the prior publication, explicate the connections between the publications and cue the reader to the content of the next publication.

The main goal of the final discussion chapter is to consolidate the main themes and critical points presented throughout the six separate, but related, research publications to both answer the research questions and ensure a clear research narrative. First, the unique and meaningful contributions of the PhD,
and the separate publications, to the primary science research literature are described explicitly. Second, the findings presented across the six publications are used to answer the research questions formally. Third, the research limitations are addressed. Fourth, key points arising from the results are discussed. Fifth a subsection will articulate the implications of this research. Sixth, the implications for science teaching practice are outlined. Finally, there is a succinct and holistic concluding statement.
Review of Literature

The following review of literature aims to orient the reader to both the state of Australian primary school science education and the necessity for addressing the emerging problems in this area of education. First, the broad goals of science education are outlined, to allow for reflection on the information presented within the following sections. Second, the state of Australian primary science education is discussed, before more in-depth overviews of the perspectives and needs of the primary science groups are presented. These stakeholders include students, teachers and tertiary institutions. Third, the approaches used in tertiary science programs are described and discussed. Fourth, a relational argument is presented to clarify the research steps needed to address some of the issues and fill gaps in the body of literature.

Introduction

The goal of science education in many western societies is to develop scientifically literate citizens (Bybee, 1997; Collins, 1997; Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007; Lumpe, Czerniak, Haney & Beltyukova, 2012). The concept of scientific literacy is multifaceted. It can be partially defined as a broad set of investigative skills and accompanying beliefs about the nature of science (NOS) (Brickhouse, 1990; Lederman, 1992; McDonald, 2010) that can be generalised to real-life situations. The development of scientific literacy is a cumulative, lifelong process that should be addressed in all stages of formal education. Goodrum, Hackling & Rennie (2001, pp. 488-494) recognise the importance of scientific literacy, and it is evident as an underlying construct within their nine themes.
describing an *ideal* state for school science education in Australia.

Specifically:

1) The science curriculum is relevant to the needs, concerns and personal experiences of students;

2) Teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world;

3) Assessment serves the purpose of learning and is consistent with and complementary to good teaching;

4) The teaching-learning environment is characterised by enjoyment in learning, and mutual respect between the teacher and students;

5) Teachers are life-long learners who are supported, nurtured and resourced to build the understandings and competencies required of contemporary best practice;

6) Teachers of science have a recognised career path based on sound professional standards endorsed by the profession;

7) Excellent facilities, equipment and resources support teaching and learning;

8) Class sizes make it possible to employ a range of teaching strategies and provide opportunities for the teacher to get to know each child as a learner and give feedback to individuals; and,

9) Science and science education are valued by the community, have high priority in the school curriculum, and science teaching is
perceived as exciting and valuable, contributing significantly to the development of persons and to the economic and social well-being of the nation.

**The Current State of Australian Primary Science Education**

Four national studies provide a comprehensive overview of the current state of Australian primary science education. These four studies (Gonski, 2011; Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007; Tytler, Osborne, Williams, Tytler, & Clark, 2008) present an opportunity to explore the factors affecting Australia’s declining levels of science achievement. First, the initial report into the *Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum, Hackling & Rennie, 2001) provides a foundation by exploring the views and actions of teachers and students. Second, Goodrum and Rennie (2007) reviewed Australian science education in light of their prior suggestions for improvement. Third, Tytler et al. (2008) conducted a comprehensive review of the Australian literature related to the state of science education. Finally, the latest review into school funding (Gonski, 2011) will provide a more contemporary perspective of the issues.

Goodrum, Hackling and Rennie (2001) conducted a comprehensive research project with teachers and students to determine what was happening, in part, in Australian primary science. The investigation found that the *actual* situation was far from the *ideal* presented by the authors (Goodrum et al., 2001, pp. 488–494). The 500 primary teachers surveyed by telephone reported an average of 59 minutes of science teaching per week. A later report by Angus (2003) indicated that the average amount of time spent in primary
science was only 41 minutes per week. If the reports are correct, science receives 4% of the available curriculum time despite being one of the six key learning areas (KLAs) in the primary curriculum. Such minimal allocation falls short of even the modest requirements (6%-10%) of the Australian National Science Curriculum (Board of Studies NSW, 2012). Many teachers cited time constraints, feelings of personal inadequacy and a lack of administrative support as reasons for the limited inclusion of science in the daily classroom curriculum.

It was widely reported by teachers that when science was taught, the lessons used *desirable* hands-on and student-centred approaches (Angus, 2003; Goodrum, Hackling & Rennie, 2001). Such “student-centred approaches” conflict directly with students’ reporting of their own science learning experiences. Nearly half of all students indicated that note taking is a large part of science. An overwhelming 75% of all student responses suggested that the majority of experiments are teacher-centred demonstrations. While these strategies certainly have a place within science education, the focus on ‘hands-on’ learning may hint at a simplistic, underdeveloped knowledge of science pedagogies within teachers. Indeed, this is quite similar to Appleton’s (2002) findings that primary teachers view tactile manipulation as a key science pedagogy whilst seemingly being unaware of the complexities of the constructs of Pedagogical Content Knowledge (PCK) (Geddis, 1993; Grossman, 1990; Lederman, 1999; Tamir, 1988), Pedagogical and Professional Experience Repertoires (PaPeRs) (Loughran Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001) and Content Representations (CoRes) (Nillson & Loughran, 2011). Unfortunately, the construct of PCK is ill-defined and difficult to operationalise into teacher education practice. This is
particularly problematic in the domain of science education as teachers struggle to find concrete teaching examples to develop their understanding of PCK. The constructs of PCK, PaPeRs and CoRes are described further in appendix eleven (p. 402).

In 2007, Goodrum and Rennie conducted a review of Australian science education to determine if their suggested strategies (Goodrum, Hackling & Rennie, 2001, pp. 488-494) had been implemented. Aside from some exemplary, isolated science programs, there appeared to have been very little change in Australian primary science education. Teachers reported many of the same obstacles, including outdated technology and external pressure from high stakes testing. Evidence of deeply ingrained negative science attitudes also emerged. For example, despite noteworthy complaints about the lack of professional development in 2001, many teachers displayed a lack of desire to attend. Moreover, primary students had poor understandings of the true nature of scientific investigation and did not believe that science was relevant beyond the classroom.

In their comprehensive review of the literature, Tytler et al. (2008) found that much of the external literature indicates that there are problems with primary science education in Australia. Amongst the variety of themes, including a lack of student engagement, limited scientific inquiry and poor perceptions of real world relevance, it appears evident that primary school science teaching is not capitalising on the natural interest and curiosity of students. A meta-analysis of survey-based literature in this area found that science was reported to be taught for a mean of an hour per week (Adams, Doig, & Rosier, 1991; Australian Science Technology and Engineering Council, 1997; Gough,
Marshall, Matthews, Milne, Tytler, & White, 1998; Lokan, Ford, & Greenwood, 1997). Tytler et al. (2008) remain sceptical of this figure; given that, preservice teachers rarely report seeing science being taught on their practical teaching placements. In fact, Tytler and Griffiths (2003) found that teachers report only three hours per term of teaching where science is the overt focus. Much of the science reported in other studies may, therefore, be an over estimate clouded by claims of loose integration.

The Gonski Report (2011) into school funding found that cultural and economic factors were contributing to the growing disparity between high and low student performance in science. Clearly, a problem exists as only 16% of Australian schools are meeting national minimum science standards, which is well below the target of 80% (Gonski, 2011). The following section discusses the science achievement and attitudes of Australian primary students.

The Science Achievement and Attitudes of Primary Students

The achievement level of Australian primary students in science has declined as other nations have advanced (Gonski, 2011). The Trends in International Mathematics and Science Study (TIMSS) assesses and compares the scientific content knowledge and scientific literacy of Year 4 students from as many as 52 nations (Thomson, Hillman, Wernet, Schmid, Buckley & Munene, 2012). Table 1.1 summarises Australia’s primary science performance in TIMSS from 1995 through 2015 (Gonski, 2011; Martin, Mullis, Beaton, Gonzalez, Smith & Kelly, 1997; Mullis, Martin, Gonzalez & Chrostowski, 2004; Martin, Mullis, Foy & Hooper, 2016; Thomson, Wernet, Underwood & Nicholas, 2008; Thomson et al., 2012). Despite consistently
scoring above the OECD average, the performance of Australian Year 4 students has declined in comparison with other countries since 1995 and more recent testing has shown stagnation. Australia’s sharpest decline has occurred in the international rankings. Nations such as Italy, Slovakia, Hong Kong and Hungary now score more highly than Australia, with nations such as Japan, Finland and Russia producing more scientifically literate primary school students. There is a large gap between high performing and low performing students in Australia. The above average students represent 27% of the total population, and they are reaching similar levels to Singaporean and Finnish students. The tail group is larger (36%) and these students are reaching similar standards to students from lower performing nations such as Armenia, Qatar and Oman. Such disparity in student science ability is likely to be another inhibiting factor in the teaching of primary science in Australia. Perhaps the most concerning finding is Australia’s fall below the ‘High threshold’ for Year 4 science performance. According to Thomson et al. (2012), a mean score of 550 (the ‘High threshold’) or above would suggest that students are able to apply science knowledge and skills to novel situations beyond the classroom context. Australia has failed to reach this level for nearly two decades. This is an indicator that primary school science educators in Australia are broadly failing to develop the scientific literacy of their students.

<table>
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<th>Year</th>
<th>Australia's Score</th>
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<td>1995</td>
<td>562</td>
<td>524</td>
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<td>521</td>
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<td>2007</td>
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<td>13th</td>
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<tr>
<td>2011</td>
<td>516</td>
<td>486</td>
<td>19th</td>
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<td>2015</td>
<td>524</td>
<td>500</td>
<td>25th</td>
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The declining state of primary science education is reflected in the science views and attitudes of primary-school students (Breakwell & Beardsell, 1992; Brown, 1976, Doherty & Dawe, 1988; Haden & Johnstone, 1983; Harvey & Edwards, 1980; Johnson, 1987; Simpson & Oliver, 1985; Smail & Kelly, 1984; Yager & Penick, 1986). Goodrum, Hackling and Rennie (2001) surveyed 1221 primary-aged students in their evaluation of Australian science education. A quarter of the students completely dismissed science as being a boring subject, whilst 27% were frustrated by the content heavy, note taking focus of science. A concerning finding was that students could only ‘sometimes’ relate their science lessons to the outside world. The lack of science literacy evident within the declining TIMSS results also re-emerged within the report into the state of Australian science education (Goodrum, Hackling & Rennie, 2001). The more recent NAP-SL student survey showed that as many as 79% of students would like to learn more science at school (ACARA, 2013). Yet on the same survey many respondents indicated that they seldom engaged in planning scientific investigations and did not feel that science was a part of their everyday life. The following section outlines the science attitudes and perspectives of primary teachers.

The Science Perspectives and Attitudes of Primary Teachers

The following sections outline and discuss the science perspectives and attitudes of primary teachers. First, the science attitudes and perspectives of inservice primary teachers are examined. Second, the science attitudes and views of preservice primary teachers are discussed in relation to their inservice counterparts.
Inservice Primary teachers

Primary school teachers generally appear to have negative attitudes towards science and science teaching (de Laat & Watters, 1995; Schibeci, 1984; Tilgner, 1990). Many teachers do not feel confident in their ability to teach science because of their inadequate science content knowledge (Goodrum, Hackling & Rennie, 2001; Harlen, 1997; Palmer, 2011; Tytler, Smith, Grover & Brown, 1999). This seems to be related to a wider dismissive attitude toward the science teaching profession. Research has indicated that both preservice and inservice teachers feel worse about the capacity of science education in general to develop science literacy than they feel about their own ability to deliver science education (Hechter, 2010; Johnston, 2003; Mulholland, Dorman & Odgers, 2004; Ramey-Gassert, Shroyer & Staver, 1996; Watters & Ginns, 2000; Yilmaz & Cavas, 2008). The following section explores the science attitudes and influences of preservice primary school teachers.

Preservice Primary Teachers

Much like their inservice counterparts, preservice teachers tend to have negative attitudes towards science and science teaching (Cobern & Loving, 2002; Howitt, 2007; Shrigley, 1974; Tilgner, 1990). Grindrod, Klindworth, Martin & Tytler (1990) surveyed 346 preservice teachers. Negative feelings towards science were reported by 51% of the respondents and 34% reported neutral feelings towards science. In a more recent study, Brígido, Borrachero, Bermejo & Mellado (2013) found that preservice teachers’ negative science views were neither simple nor universal. A sample of 188 preservice teachers responded to a survey that measured science efficacy and emotions. The preservice teachers displayed negative emotions towards ‘hard sciences’ (i.e.,
chemistry, physics) because they believe these disciplines are difficult to relate to their lives and experiences beyond school. The participants had positive views of biology and geology because of their perceptions about the external relevance of the topic areas.

The inadequate science knowledge of some preservice teachers is related to poor personal and educational science experiences (Jarrett, 1999; Palmer, 1995; Skamp & Mueller, 2001; Skamp 1995; Young & Kellogg, 1993). Mulholland and Wallace (1996) noted that all the preservice teachers interviewed within their study displayed negative attitudes towards their experiences of science in their primary school years. Some studies have shown that preservice teachers have very few memories of primary school science (Skamp, 1997), which is likely to be a reflection of the limited science being taught within primary schools (Goodrum, Hackling & Rennie, 2001). Of the 22 participants interviewed, only 23% reported memories of science being taught well in primary school. In fact, two of the participants had bad memories of their science learning in primary school. Jarrett’s (1999) research revealed that preservice teachers might have the potential to enjoy science despite their earlier detrimental experiences. Approximately half of the 112 preservice teachers surveyed and interviewed had strong positive memories of their own, personal science pursuits, even though 70% of the sample population showed either negative or neutral memories of their primary school science experiences. This is markedly similar to the discord between personal science and school science reported at the primary school level. Despite such issues, there is clearly potential to alleviate the negative attitudes that exist within preservice teachers. Thus, the next section outlines
the state of tertiary teacher education programs in relation to primary science education.

The State of Tertiary Science Education for Preservice Primary Teachers

The approaches to preservice primary science education are diverse (Palmer, 2008); which may lead to inconsistent graduate science teaching standards feeding existing cycles of science education decline. Team teaching, cross-faculty collaboration and weekly content focuses are the most common features of science courses delivered to preservice primary teachers (Avery & Meyer, 2012; Bybee, 2014; Jung, 2004; Palmer, 2008; Sindel, 2010; Yilmaz & Cavas, 2014). Content-heavy curriculum, with weekly focus shifts, has been condemned as disjointed, which is inconsistent with the true nature of scientific investigation and of not facilitating the depth of learning needed to remediate science content knowledge deficits (Bybee, 2014).

There are markers, such as inquiry learning, problem-based learning and cooperative learning, within the literature that serve to highlight avenues for potential improvement in primary science preparation programs. Inquiry learning has value beyond its close alignment with syllabus imperatives (NSW Board of Studies, 2012) and best practice primary science programs such as PrimaryConnections (Hackling, 2006), because research shows links to improved integrated learning (Saçkes, Felvares, Gonya, & Trundle, 2012), science teaching efficacy and science content knowledge (Luera & Otto, 2005). Problem-based learning scenarios have been used to provide rich, real world contextualisation for skills of scientific inquiry (Huinker & Madison, 1997; Logerwell, 1997; Watters & Ginns, 2000). In fact, a sample of 159 preservice primary teachers developed more nuanced, sophisticated
understandings of science pedagogy (Ford, Fifield, Madsen & Qian, 2012) as they experienced a PBL science course. They progressed from the more basic conceptualisations such as ‘hands-on activities that work’ that are commonly reported within the science education research (Appleton, 2003; Appleton & Kindt, 2002; Ertmer, Schlosser, Clase, & Adedokun, 2014). Still, PBL is not a pedagogy without risk (Watters, 2007) and considerable structure and support are needed for effective implementation in tertiary science education programs.

Cooperative learning is an educational construct where a group of students work together to develop their knowledge and skills through the achievement of a clearly defined goal. Cooperative learning is supported through the principles of social constructivism that have underpinned educational theory for decades (Ruys, Van Keer & Aelterman, 2010; Santrock, 2007; Vygotsky, 1977). According to Blosser (1993) participants need to make meaningful contributions to a task that cannot be achieved by a single individual. Thus, participants need to develop and use interpersonal and reflective skills. Cooperative learning has been clearly linked to improved outcomes and attitudes for tertiary learners (Kyndt, Raes, Lismonst, Timmers, Cascallar, & Dochy, 2013; Tsay & Brady, 2010). Palmer (2006) used cooperative learning as a key component of his science methods course targeting second year preservice primary teachers. The results showed significant increases in both the personal and general science teaching efficacy beliefs of the participants that were durable for up to a year after the completion of the subject.

Firsthand science teaching experiences can play a central role in the delivery of quality tertiary science education (Bhattacharyya, Volk & Lumpe, 2009;
Ebrahim, 2012; Palmer, 2011; Wingfield & Ramsey, 1999). Claims have been made that practical science teaching experiences are related to significant, durable growth in both preservice teachers’ science teaching efficacy beliefs and science attitudes (Palmer, 2011; Wingfield & Ramsey, 1999). In order to reap the benefits of firsthand science teaching, these experiences need to be contextualised within a structured science course, as practical science teaching alone has little influence on the preservice teachers (Ebrahim, 2012). This leads to an important question, “how can different innovative approaches be combined to create effective science learning opportunities for preservice primary teachers?” This is a complicated question as different course designs, varying measures of success and issues of replicability must be considered.

Even though there are many established innovative approaches, many preservice science educators are electing to limit the number of innovative approaches utilised within their subject designs (Lawrance & Palmer, 2003; Palmer, 2008). Indeed, the content-heavy, isolated topic approaches that are often used may hinder the meaningful integration of multiple innovative practices. Bybee (2014) has recently called for an end to such fragmented approaches to university science education through the use of intensive, integrated approaches that afford preservice teachers the opportunity to engage in first-hand scientific investigations. In essence, an understanding of ‘what’ innovations are effective has been reached. It now needs to be determined ‘how’ the innovations should be employed in broader subject and program structures to affect the best outcomes for prospective primary science teachers. The following section narrows the research focus in order
to position this doctoral research by showing how a meaningful and achievable contribution to the existing body of literature can be made.

**Filling the Gaps and Narrowing the Focus of the Research**

It has been established that the problems with science education are both complex and difficult to solve. An unusual situation has emerged where the potential solutions to these problems are as vast, and potentially unwieldy, as the problems themselves. In order to determine the most worthwhile areas for future research, it is worth evaluating the capacity of each group to address the issues that exist within primary science education. Primary students have the least impact on the system itself, despite potentially being the most important group. Primary teachers have the most direct impact on the quality of science teaching as they deliver the intended curriculum directly to students. Research has shown that science interventions can improve the science teaching attitudes and science PCK within both inservice and preservice teachers (Fitzgerald, McKinnon, Danaia & Deehan, 2016; Holden, Groulx, Bloom, & Weinburgh, 2011; Watters & Ginns, 2000). It could be argued that tertiary teacher training programs should be pivotal to sustained, legitimate improvement of the quality of science education because they have the widest sphere of influence.

It may be more valuable to invest time and resources focusing on the development of preservice teachers rather than inservice teachers. Even so, inservice professional development science workshops can lead positive outcomes for primary teachers. Duran, Ballone-Duran, Haney, and Beltyukova (2009) found that the Active Science Teaching Encourages Reform (ASTER III) improved the science-teaching efficacy and inquiry
teaching practices of 26 inservice primary teachers. The participants reported greater confidence in their capacity to use active, student-centred teaching pedagogies and collaborate with their peers. However, it should be noted that the program required considerable time and financial commitment, within an implementation and support period of 18 months. Clearly, professional development workshops can address some of the science issues frequently seen within practicing teachers, but these are hindered by considerable time restraints, financial requirements and a noted need for ongoing support to ensure change. While preservice teachers represent a more attainable group, inservice teachers should remain an integral aspect in future attempts to improve science education. Ideally, research into the tertiary science experiences of preservice teachers should begin to adopt longitudinal approaches to determine how such experiences impact the science teaching practices of early career teachers (McKinnon & Lamberts, 2014).

The increasing mean age of Australian teachers may further diminish the broader impact of a potential focus on inservice teachers (Harris & Farrell, 2007). In 1986, the mean age of an Australian teacher was a mere 34 years, but by 2001, this had risen to 45 years (ABS, 2003; MCEETYA, 2003). By 2011, approximately 55% of primary teachers in NSW were over 50 years old. This represented a decline in the over 45 demographic, hinting that the peak had already passed. Figure 1.1 shows a projected age distribution of NSW primary teachers in 2020 based on data collected in 2010 and 2015 (NSW DE, 2015). As of 2016, approximately 19,000 teachers are aged between 45 and 60 years old. As the baby boomer generation retires, it is expected that there will be a more even age spread with younger teachers representing a larger proportion of the entire teaching workforce (NSW DEC, 2016).
2011; NSW DE, 2015). Thus, a heightened focus on changing the science attitudes and developing the science PCK of preservice teachers is likely to have a considerable impact on both the science attitudes and performance of Australian students.

![Age distribution of NSW teachers](image)

**Figure 1.1** Age distribution of NSW teachers

The state of primary science education should be of paramount importance, as steps are taken to rectify the overall declines in the quality of Australian science education as a whole. Primary school science classes are the first formal science experiences for all Australian citizens. If inadequate time is dedicated to these formative science experiences, or students are exposed to disengaging pedagogical approaches, then they are likely to begin to form the negative attitudes toward science that are evident throughout all levels of formal science education. Poor quality primary science teaching could have inter-generational impacts as many teachers express negative feelings about their own personal primary science learning (Jarrett, 1999; Mulholland & Wallace, 1996). This aligns with the body of literature that indicates declines in attitudes toward science are most apparent from the age of 11 onwards.
(Breakwell & Beardsell, 1992; Brown, 1976, Doherty & Dawe, 1988; Hadden & Johnstone, 1983; Harvey & Edwards, 1980; Johnson, 1987; Osborne, Simon & Collins, 2003; Simpson & Oliver, 1985; Smail & Kelly, 1984; Yager & Penick, 1986). Similar declines are evident in the science achievement of primary school students. The evidence indicates that the problems with primary science have the potential to impact learning at higher levels and therefore need to be addressed.

There is a large body of research that highlights the positive impacts that tertiary science programs can have on preservice primary teachers (Cooper, Kenny & Fraser, 2012; Mullholland, Dorman & Odgers, 2004; Ramey-Gassert, Shroyer & Staver, 1996; Wang, 2002). However, the current state of the system has failed to improve the mean science achievement of students, foster positive attitudes towards science or produce scientifically literate citizens.

This PhD will fill a gap in the literature by exploring how tertiary science programs influence the science teaching efficacy and science teaching experiences of inservice primary teachers. Other variables are discussed in appendix 11 (p.402). The following section presents the research questions and aims that underpin the proposed research.

**Research Questions and Aims**

This section outlines the three research questions. Key aims are listed beneath the research questions to create a direct link to the proposed papers. These proposed research questions are:
1) How are the science-teaching efficacy beliefs of both preservice and inservice primary teachers represented within research literature and subsequently addressed through interventions?

The aims underpinning Question 1 are:

- To compare the effects of different pedagogical approaches undertaken in preservice teaching programs on science teaching efficacy (Publication One).

- To provide a clear perspective of how the STEBI-B is being employed methodologically within the growing body of literature (Publication One).

- To assess the detail and accuracy of the intervention descriptions for the purposes of future research replication (Publication One).

- To compare the effects of different pedagogical approaches undertaken in professional development workshops as outlined via the STEBI-A instrument (Publication One).

- To explore the trends in the science teaching efficacy beliefs of inservice primary teachers in a variety of contexts (Publication One).

- To provide a clear perspective of how the STEBI-A is being employed methodologically within the growing body of literature (Publication One).
To assess the detail and accuracy of the intervention descriptions for the purposes of future research replication (Publication One).

2) Does preservice primary teacher participation in two complex, innovative and complementary courses co-vary with improvement in science teaching efficacy beliefs and positive science teaching perceptions?

The aims underpinning Question 2 are:

- To determine how two complex, innovative science subjects can affect the science teaching efficacy beliefs of a cohort of preservice primary teachers (Publications Two, Three, Four and Six).

- To explore how action research can be used to improve the educational design of science courses (Publications Two and Six).

- To investigate longitudinally the science teaching efficacy beliefs and science experiences of a cohort of preservice teachers as they transition into early career graduate teachers (Publication Three, Four and Five).

- To assess the durability of science teaching efficacy belief changes that occur within the two science subjects delivered in a tertiary context (Publication Three).
To explore a cohorts’ science experiences beyond the tertiary context (i.e. practical experience placements and early career teaching) and determine how these compare and relate to their science program experiences (Publication Five).

To assess the impact of two science-education subjects on the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers over an extended eight-year period (2005-2013) (Publication Five).

To determine if one of the innovative science courses can be transitioned successfully from a face-to-face mode of delivery to an online mode of delivery (Publication Six)

3) How do the complex, innovative science courses appear to impact the long-term science teaching efficacy beliefs and reported science teaching practices of past preservice teachers who have transitioned to inservice status?

The aims underpinning Question 3 are:

- To compare the effects of different pedagogical approaches undertaken in preservice teaching programs as outlined via the STEBI-B instrument (Publication One).

- To longitudinally investigate the science teaching efficacy beliefs and science experiences of a cohort of preservice teachers as they transition into early career graduate teachers (Publication Three, Four and Five).
• To assess the impact of two science education subjects on the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers over an extended 8 year period (2005-2013) (Publication Four).

• To determine if a covariant relationship exists between preservice teachers’ participation in an integrated science subject with multiple innovative practices and their increased science teaching efficacy beliefs (as defined by STEBI-B (Publications Three, Four and Six).

• To assess the science teaching efficacy beliefs of primary teaching graduates who experienced the innovative, student centred science education program (Publication Five).

• To assess the durability of the science teaching efficacy changes experienced by teachers, during their preservice science education (Publication Five).

• To contribute to the existing STEBI-A research with a broad, cross sectional administration of the STEBI-A instrument graduate teachers (Publication Five).

• To explore how CSU graduate primary teachers perceive their science teaching efficacy beliefs and science teaching practices in relation to their tertiary and professional experiences (Publication Five).
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Publication One

The Science Teaching Efficacy Belief Instruments (STEBI A and B): A comprehensive review of methods and findings from 25 years of science education research

Publication one has been published as a Springer Brief in Science Education. Language and formatting have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Research Conceptualisation
- Data Collection
- Data Analysis
- Manuscript Drafting
- Manuscript Editing

An online version of the first publication can be accessed here -

James Deehan

The Science Teaching Efficacy Belief Instruments (STEBI A and B)
A Comprehensive Review of Methods and Findings from 25 Years of Science Education Research
The Science Teaching Efficacy Belief Instruments (STEBI A and B)

A Comprehensive Review of Methods and Findings from 25 Years of Science Education Research

Springer
Abstract

Science education is currently undergoing a transformation. Students’ science interest and achievement levels are waning despite the increasing importance of scientific literacy. Globalisation and technological advancement have raised the bar for economic participation. Therefore, it has become imperative to assess the existing body of science education research. Science education, like all forms of education, is innately difficult to evaluate as achievement outcomes are challenging to quantify and variables remain complicated to account for and control. Amidst a plethora of measures, teacher efficacy has been shown to have positive relationships with teacher resilience, reported use of student-centred teaching strategies and student outcomes. The Science Teaching Efficacy Beliefs Instruments A and B (STEBI-A/STEBI-B) were published 25 years ago as valid and reliable measures of the science teaching efficacy of both pre-service and in-service teachers. Both instruments have become pillars in science education research with a combined citation rate of over 1,400. The value of the STEBI instruments cannot be overstated as both allow for research comparisons across teaching contexts (in-service and pre-service), historical contexts (25 years of research) and national contexts (more than 10 contributing nations). The purpose of this Springer Brief is to provide a comprehensive review of the both the STEBI methods and findings through the use of a clearly defined analytic framework. A systematic review of literature yielded 107 STEBI-A research items and 140 STEBI-B research items. The STEBI instruments have been used in a wide range of qualitative, cross sectional, longitudinal and experimental designs. Analysis of the STEBI research findings reveals that in-service and pre-service programmes which use innovative practices such as cooperative learning, inquiry-based investigation and nature of science instruction can produce positive growth in participants’ science teaching efficacy beliefs. The personal science teaching efficacy beliefs of pre-service and in-service teachers showed greater mean scores and higher growth than their outcome expectancies. The implications of the findings in this review are discussed fully in the book.
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### Acronyms

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<tr>
<td>ES</td>
<td>Effect Size</td>
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<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
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<td>KLA</td>
<td>Key Learning Area</td>
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<td>NOS</td>
<td>Nature of Science</td>
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<td>PBL</td>
<td>Problem-based Learning</td>
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<td>PCK</td>
<td>Pedagogical Content Knowledge</td>
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<tr>
<td>PISA</td>
<td>Programme for International Student Assessment</td>
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<tr>
<td>PSTE</td>
<td>Personal Science Teaching Efficacy beliefs</td>
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<td>STEBI-A</td>
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</tr>
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</tr>
<tr>
<td>STEM</td>
<td>Science Technology Engineering Mathematics</td>
</tr>
<tr>
<td>STOE</td>
<td>Science Teaching Outcome Expectancies</td>
</tr>
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<td>TIMSS</td>
<td>Trends in International Mathematics and Science Study</td>
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Chapter 1
Introduction

Much has been said about the crucial role that science has played, and will continue to play, in shaping our societies. For most of us, science conjures images of keystone events in history that have advanced the sum of human knowledge. We consider Charles Darwin’s work with the Galapagos Finches, the Moon landing, the discovery of water on Mars and, most recently, evidence indicating the existence of gravitational waves and we marvel at the capacity of human ingenuity. Yet, despite our societies’ apparent value of science, it is hard not to feel a sense of disconnect. We didn’t form the theories, we didn’t conduct the research and we didn’t perform the analyses. The unseen barrier between the scientific community and the rest was summed up succinctly by a peer during my undergraduate studies “I can see the value of science but I’m not a sciencl person”. Upon reflection years later, I came to see this statement as an indictment on this person’s fundamental science educational experiences. It was disheartening to hear that a person, with the intellectual capacity to study at the tertiary level, had categorised their scientific disengagement as an innate personal characteristic. This cannot be accepted, science must be for all. The scientific discoveries made by the elite few must be reconciled with the beliefs and understandings of the many; for that is the structure of most truly democratic nations.

Science education is of paramount importance if scientific innovations and discoveries are to continue having meaningful, positive impacts on cultures and societies. In a search for a perspective from an alternate viewpoint, I once asked my mother what she believed the purpose of science education to be. Seizing that I may have been engaging her in an unwanted slow-walk to my own conclusion, she replied with a wry smile, “To train scientists of course!”. Her brazen oversimplification had the desired effect as I smiled, sipped my coffee and changed the topic of conversation. The fundamental purpose of science education is to develop scientifically literate citizens. Scientific literacy is comprised of more than the rote recall of existing knowledge; it is a malleable array of skills and beliefs that are generalisable to real-world situations (Bybee 1997). In a practical sense a scientifically literate person would be able to access and interpret information from various sources to reach reasoned, evidence based conclusions whilst avoiding...
common pitfalls of logical fallacies. The need for scientific literacy is evident throughout most areas of modern society. From an economic perspective, job requirements have changed over the past half a century to more closely resemble the cognitive processes of scientific literacy. Coding and analysis of Census data from the United States over the past 4 decades has shown that Expert Thinking and Complex Communication are the only two skills to have grown in terms of workforce composition (Levy and Murnane 2006). Even environmental issues such as climate change require citizens to both navigate and respond to abundant information and perspectives. It is through the lens of scientific literacy that science education should be judged.

Most citizens will develop their base level of scientific literacy through elementary and secondary science education experiences. Aside from achievement scores, student engagement with science is dwindling. It could be argued that, rather than captivating students, science education can have a filtering effect. This filtering effect begins at the elementary level where students bemoan the passive, note-taking pedagogies associated with science classes (Goodrum et al. 2001; Goodrum and Reanie 2007). This is certainly not a new phenomenon as negative science attitudes in students have been reported for decades (Breakwell and Beardsell 1992; Brown 1976; Doherty and Dawe 1988). We are now at a pivotal time as generational cycles of science disengagement could become more deeply rooted in our cultures. According to DeWitt et al. (2014) students’ attitudes towards science reaches a steep tipping point at the age of 14 where their engagement with science becomes even more difficult to salvage. This is reflected in reduced rates of post-compulsory science uptake in secondary science education as students elect to separate themselves from science completely (Abraham 2013; Ainley et al. 2008; Hughes et al. 2012; Lyons and Quinn 2010; Osborne et al. 2003). Thus we have the beginnings of the societal disconnect from science that was discussed earlier.

The Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) allow for the science achievement of students to be assessed at global levels. Nations such as America, Australia, England, Japan and New Zealand have all show stagnation and/or decline in the science achievement and scientific literacy of their 4th grade students over the past decade (Martin et al. 1997, 2004, 2008, 2012; Thomson et al. 2008, 2011). TIMSS and PISA data taken from secondary students show similar patterns of decline both in terms of mean scores and international rankings for the aforementioned nations (Beaton et al. 1996; Lemke et al. 2001; Martin et al. 2004, 2008; OECD 2004, 2007, 2010, 2013). Copious numbers of elementary and secondary students appear unable to connect their classroom science learning with the world around them. An undeniable truth has emerged for the nations whose students are performing below high threshold standards: science education is failing in its goal to develop a scientifically literate populace. The collective failure of science education notwithstanding, there is still “hope” as the inquisitive, curious nature of youth cannot be fully extinguished. Indeed many elementary students express a desire to learn more science even though they are seldom
active participants in the inquiry process and do not view science as a part of their everyday lives (ACARA 2013).

Finding solutions to the issues with science education is no simple task. The sheer array of stakeholders, variables and potential intervention programs is behemoth. While students represent the key target for change and growth, they remain primarily passive within science education systems. Teachers must play a key role in providing inclusive science education experiences that enhance the scientific literacy of their students. Evaluating preservice and inservice teachers has been an academic and political hot potato for decades and this is not a discussion I intend to contribute to here. One viable construct, among many, is teacher self-efficacy. Bandura (1977) linked an individual's efficacy beliefs with the initiation and sustainment of coping behaviours when experiencing adverse conditions. Gibson and Dembo (1984) developed a valid and reliable instrument for measuring teacher efficacy. Teacher efficacy can be defined as the confidence an individual has in themselves or their profession to help students to achieve pre-determined educational outcomes. The seminal work of Gibson and Dembo (1984) established links between teaching efficacy and other variables such as: use of student centred pedagogies, lower rates of teacher criticism and persistence in difficult professional circumstances. Ghaith and Yaghi (1997) found that teachers with high personal teaching efficacy beliefs were more likely to have open attitudes towards the implementation of new instructional practices. Teacher efficacy has made the intangible tangible as researchers now have a reliable and valid measure for a construct that has established links to many of the factors that contribute to an educational environment. Over the decades efficacy has become a cornerstone for educational research as variable relationships have been established, interventions have been assessed and more efficacy instruments have been developed (Dellinger et al. 2008; Ritter 1999; Tschannen-Moran and Woolfolk Hoy 2001; Smollock et al. 2006).

For the field of science education, the Science Teaching Efficacy Belief Instruments A and B (STEBI-A/B), for inservice and preservice teachers respectively, have been research linchpins for over 25 years (Enochs and Riggs 1990; Riggs and Enoch 1990). The STEBI instruments have proven to be valid and reliable measures of both personal and general science teaching efficacy beliefs across a variety of contexts (21 contributing nations to be precise!). I was first introduced to the STEBI instruments by my Honours/Doctoral supervisors, Professor David McKinnon and Doctor Lena Danaia, as an overenthusiastic undergraduate research trainee in 2011. David and Lena had been using the STEBI-B instrument in an action research model to evaluate, and subsequently refine, a science program for preservice elementary teachers. I trawled through the STEBI literature and was awestruck by the variation in contexts, purposes, approaches and research designs. A 25-year body of literature seemed endless, but perhaps in a display of the naivety of a neophyte researcher I felt compelled to conquer it. I struggled to reign in my STEBI searching, writing and discussion. There was always more. More viewpoints, more findings, more contradictions, more interventions, more contexts and, above all, more ideas. I soon realised that
a thorough review of the STEBI literature needed to be conducted or the messages would soon be lost in the sheer, and increasing, volume of contributions. My apologies for the clichéd, lazy but nonetheless accurate metaphor in advance. I felt that I was holding and using a series of puzzle pieces in isolation without ever having put the puzzle together to see the big picture.

The big picture is now available for you. This Springer Brief presents an unprecedented review of 25-years of STEBI-A and STEBI-B literature (combined citation rate of over 1400). A structural framework is used to analyse and organise the STEBI literature in terms of research designs and findings. This two-phase analytic approach has allowed for the diverse array of STEBI research to be analysed. You will find analyses on the research contexts, subscale use and effect sizes of the STEBI instruments. The STEBI-B research designs are described and critiqued at different levels. Rather than attempting to make broad statements on the quality of the research analysed, the levels have been determined based on the number of STEBI uses within the research design. Such an approaches allows for the unique purposes and contexts to be considered, as comparisons are made where appropriate, rather than universally.

The purpose of this book is not to provide solutions to the issues with science education. That is a task for those with more expertise than I. Over the past quarter of a century many dedicated and insightful researchers have made meaningful contributions to the sustained improvement of science education. Thus, the purpose of this book is to bring together these isolated contributions to form a single, collective overview of how STEBI research has advanced the sum of human knowledge and affected meaningful change across different science education contexts. For too long I, much like many early career researchers, have “stood on the shoulders of giants”. *Glances knowingly at the Google Scholar homepage* Perhaps it is time, with the rapid influx of research across emerging platforms, for the giants to be elevated once more.

I urge you, the reader, to extract what you need from this book. For the researchers, the convenience, clarity and power of the reviews (247 articles and dissertations) cater for the demands of PhD students all the way through to established, late career science education researchers. This Springer Brief provides the information needed to make informed research choices. The deep referencing throughout the document can act as a hub for readers to access existing research that suits their needs and interests. For the practitioners (lectures, teachers, subject writers and policy makers), the summary of intervention outcomes can assist you to make informed choices about the design of pre-service and in-service science education programs. The strength of 25 years of comparable literature builds a compelling argument for rich, complex and student-centred science teacher education programs. The definitions of pedagogical innovations, research summaries and deep referencing assist in making this field of research accessible to practitioners and decision makers. This STEBI review could have a tangible impact on how science education programs are designed and delivered. However, a tangible impact is entirely dependent on how you, the reader, respond to the information presented in the following chapters. Let us promote scientific literacy one step at a time.
References


Chapter 2
A Review of the Science Teaching Efficacy Belief Instrument B: Pre-service Teachers

Abstract In a world undergoing rapid social, cultural, economic and environmental changes it is imperative to have an informed populace that is capable of displaying the scientific literacy needed to contribute to informed decision making. It is the people, rather than the scientists, that will decide our futures. Tumultuous times call for strong fundamental science education. As the Baby Boomer generation edges towards retirement, it is worth supporting and assessing our future generations of science teachers. Teacher efficacy is a viable means of conducting such assessment as it has shown to relate to pedagogical choices, teacher resilience and student outcomes. The Science Teaching Efficacy Belief Instrument B (STEBI-B) was initially published in 1990 and since this time has proven to be a valid and reliable measure of the science teaching efficacy beliefs of pre-service teachers. The purpose of this chapter is to review the STEBI-B instrument in terms of both methods and findings. Additionally, a framework for the systemic analysis of the literature is presented. A total of 140 articles, dissertations and presentations were included in the analyses. Findings show considerable research design variation. A plethora of student centred science interventions have shown to increase pre-service teachers’ science teaching efficacy beliefs. Pre-service teachers’ personal science teaching efficacy beliefs consistently show high scores and growth than their outcome expectancy beliefs. Implications are discussed within the chapter.

The Science Teaching Efficacy Belief Instrument—B

The Science Teaching Efficacy Belief Instrument B (STEBI-B) is a 30-item survey which was specifically designed to measure the science teaching efficacy of pre-service elementary school teachers (Enochs and Riggs 1990). This survey requires respondents to rate their level of agreement with statements on a 5 point Likert scale (Burman 2000), ranging from ‘strongly disagree’ to ‘strongly agree’. The statements produce measurements of two subscales. The Science Teaching Outcome
Expectancy (STOE) belief scale measures the participants’ broad views of science teaching related to why pupils perform as they do. An example of an item on the STOE subscale is “when a student does better than usual in science, it is often because the teacher exerted a little extra effort”. The Personal Science Teaching Efficacy (PSTE) scale measures the participants’ beliefs about their own ability to teach science effectively. An example of an item on the PSTE subscale is “even if I try very hard, I will not teach science as well as I will most subjects”.

Although other instruments, such as the Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) instrument (Ritter 1999), have been developed, the STEBI-B is frequently used within the science education research domain due to its capacity to measure relevant, complex constructs in a reliable way. When Enochs and Riggs created the STEBI-B instrument in 1990, the PSTE and STOE subscales were found to have Cronbach Alpha reliability coefficients of 0.90 and 0.76 respectively. A recent investigation (Deehan 2013) found that the STOE produced a Cronbach’s alpha of 0.798 which appears to, in a small way; quell the growing doubts about the reliability of the STOE subscale (Hechter 2010; Johnston 2003; Mulholland et al. 2004; Ranney-Gassett et al. 1996; Watters and Ginns 2000; Yilmaz and Cavas 2008). The reliability of the STEBI-B will be unpacked further in the discussion section of this chapter.

The Research Contexts of the STEBI-B Instrument

After a relatively limited research uptake in the 1990s (16 studies) the use of the STEBI-B instrument increased by approximately 900% in the new millennium. This could be partially attributed to: increased awareness of the instrument internationally, an increased interest in exploring the problems associated with science education and the growth in options for publishing research globally.

The majority of the STEBI-B research originates from the USA. Significant amounts of research have also been emerging from Australia and Turkey. The differences in social, cultural and educational factors amongst these nations provide worthwhile checks and counterbalances for the American research findings. In fact, researchers themselves have recognised potential in such collaboration, as various formal connections between the three key nations are present within the body of literature (e.g. Çakıroğlu et al. 2005; Rogers and Watters 2002). These three nations (USA, Turkey and Australia) account for 91.4% of the current STEBI-B research. Unfortunately, there does not appear to be any other nation on the cusp of matching the research contributions of the main nations. There may be opportunities for more international collaboration as researchers from Austria, the Bahamas and Greece have made meaningful contributions to the STEBI-B literature since 2014. Figure 1.1 compares the STEBI-B research output internationally. Aside from following a similar pattern of increased research output after 2000, the global research is appearing sporadically.
Fig. 1.1 Summary of the STEBI-B use of different nations

Purpose of This Study

There are four aims that underpin this chapter, with the first aim setting the structure for those to follow. The first aim is to articulate a coherent framework for organising and discussing the STEBI-B literature in a way that considers the inherent complexity of science education research without attaching undue value judgements to researchers’ choices. This framework is applied to the STEBI-A review in the second chapter. The second aim is to provide a clear overview of how the STEBI-B is being employed methodologically within the growing body of literature. In a logical progression from context to instrument, the third aim is to describe how the STEBI-B subscales (PSTE and STOE) are being employed within the literature base. The final aim is to compare the effects of different pedagogical approaches undertaken in pre-service teaching programs as outlined via the STEBI-B instrument.

Method

This research has been conducted through the use of a structural framework to comprehensively review the body of STEBI-B literature. The intention of this research is to explore the trends which have emerged within the science education literature that has employed the STEBI-B instrument. Due to the open-ended, inductive nature of review paper, the author has chosen not to list specific research questions as this could limit potential findings and inductive trends. It should be noted that the reliability (Cronbach’s alpha) of the STEBI-B instrument itself is
not the focus of this paper. The aspects that will be the focus of classification and analytic procedures in this review are: context, research design, interventions, participant numbers, subscale use and Cohen’s D effect sizes.

The following subsections will outline the procedures for both how research papers were collected for inclusion in this review and what analytic processes were undertaken to evaluate the literature. The first subsection will outline the inclusion criteria and the literature search techniques. The coding and analysis subsections will present deep explanations of the coding and analytic procedures for the methodological and intervention analyses.

**Initial Inclusion Criteria**

To adhere to the purposes of this review paper a single broad (Suter 2006) criterion was employed during the initial literature searches. This criterion was that the STEBI-B instrument is used to inform the research in a meaningful way. This accounts for the diverse contexts within which the STEBI-B instrument can be used.

**Initial Literature Collection Procedures**

The initial search for literature occurred in 4 phases.

1. **Seminal author search**—The article describing the development of the STEBI-B instrument by the seminal authors (Kervin et al. 2006) was found using ‘Google Scholar’.


   A backward mapping search (Green et al. 2006) was used to track articles that had referenced this seminal article. The seminal author search yielded 255 articles, 111 of those were deemed relevant for this review.

2. **ERIC Search**—The Education Resource Information Centre database was specifically searched with the use of the following terms:

   ‘STEBI-B’—Two papers of the 20 presented fulfilled the inclusion criteria.

   ‘Science Teaching Efficacy Belief Instrument B’—Four papers of the 50 presented fulfilled the inclusion criteria.

3. **Primo Search**—The Primo search website was used to search for relevant literature. In addition to the previously mentioned databases, Primo provides access to journal articles, newspaper articles, books, Ebooks and other forms of
‘STEBI-B’—This search yielded no relevant results.

‘Science Teaching Efficacy Belief Instrument B’—This search term yielded two additional papers.

4. Branching off Bibliographies—The final step of the literature search was to read the introductions, discussions and reference lists (Green et al. 2006) of the collected papers in order to identify articles of research that had not been collected within the previous steps. The most recent papers were searched initially. This strategy yielded no new, relevant STEBI-B articles.

A total of 117 relevant research items were collected during the initial literature collection phase.

Additional Data Base Searches

After consultation with a literature search expert, additional data base searches were employed with the intent to supplement to earlier procedures. The key search terms that were used for each database were ‘STEBI-B’ and ‘Science Teaching Efficacy Belief Instrument B’. The following databases were searched in this phase of the literature search: EBSCO Host, Cambridge Journals, CBCA Database, Emerald, Expanded Academic ASAP, Infotrac, Factiva, Infotmit, Web of Knowledge, JSTOR, Oxford Journals, ProQuest, SAGE Journals Online, ScienceDirect (Elsevier SD), Scopus, Springerlink, Taylor & Francis Online, and Wiley Online Library. Another 34 relevant pieces of research were acquired through these additional data base searches. At the conclusion of the literature search phase, 151 articles were collected that appeared to meet initial inclusion criteria.

A Complementary STEBI-A Search

The STEBI-B instrument is the pre-service equivalent to the Science Teaching Efficacy Belief Instrument A (STEBI-A) (Riggs and Enochs 1990). Both instruments are based on the same core items, measuring the same subscales, with slight phrasing modifications to suit the separate contexts. As both the STEBI-A and STEBI-B instruments were published by the same authors in the same year, the researcher believed that some relevant STEBI-B research may be misrepresented in the STEBI-A body of literature. The aforementioned literature search strategies were employed for the STEBI-A instrument. A total of 12 STEBI-B research items were found in this manner. This took the total number of STEBI-B research items to 163. The final number was reduced to 140 pieces of research that incorporated the STEBI-B instrument after 23 repeats, alternates and inappropriate articles were
Coding and Analysis

The research items selected for this review were coded in different ways to allow for holistic analyses to be conducted. The coding was used to differentiate the research approaches and the interventions employed. The following subsections will articulate the coding procedures for the research approaches, science interventions and the use of Cohen’s D effect sizes to evaluate the science interventions.

Research Approaches

The coding of the research methods employed was centred on the use of the STEBI-B instrument. As a result the frequently discussed balance between qualitative and quantitative approaches was not an overt focus, but emerged sporadically throughout the analyses. The research items were coded based on the number of administrations of STEBI-B instrument, the contexts in which the administrations occurred and how the data was analysed and presented. Table 1.1 below outlines the code descriptions for the different research approaches.

To gain a deeper understanding of the body of literature, the research pieces were coded in different ways where appropriate. Firstly, the subscale differentiation (PSTE and STOE) was coded on a 3-point scale. A score of zero indicated that the subscale was not present, a score of 1 indicated that the subscale was merged, and a score of 2 indicated that the subscale was present. Secondly, the descriptive statistics of the qualifying studies were coded in terms of overall quality, within an underlying focus on the calculation of Cohen’s D effect sizes for intra-study comparisons. A score of 2 indicated all necessary statistics have been presented. A score of 1 indicated that some necessary statistics have been presented. A score of 0 indicated that the descriptions were not clearly presented.

Intervention Coding

The interventions employed within the research papers were coded based on the pedagogies included within a science intervention. A framework of pedagogical elements was developed primarily from Lawrance and Palmers’ (2003) description of innovative practices within tertiary science programs in conjunction with wider literature reading. The researcher acknowledges that this is not an exhaustive list of potential pedagogical approaches. The argument could certainly be made that several of these innovative practices overlap. This is unavoidable as many are designed to provide students with control over their learning. For example, one could make the claim that constructivism is an integral component of many other innovative practices. There are, however, subtle differences between the innovative practices in terms of pedagogies, contexts, intended learning outcomes and overall
<table>
<thead>
<tr>
<th>Code</th>
<th>Research type</th>
<th>Number of STEBI-B uses</th>
<th>Description</th>
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<tbody>
<tr>
<td>4</td>
<td>Experimental design</td>
<td>&gt;2</td>
<td>Experimental research designs allow for cause and effect statements to be made rather than correlational observations. Two groups comprise this research design. The experimental group is exposed to a formal treatment. A control group does not receive the same treatment. Where possible extraneous variables are controlled through randomised group assignment. However, in educational research it is often ethically impossible to randomly assign participants to either group.</td>
</tr>
<tr>
<td>3</td>
<td>Longitudinal quasi experimental pre/post design</td>
<td>&gt;2</td>
<td>Research where a pre and post-test STEBI-B implementation is supplemented by delayed testing to determine the longevity of any efficacious changes in the absence of formal science treatment.</td>
</tr>
<tr>
<td>2.5</td>
<td>Quasi Experimental pre/post—with multiple cohorts</td>
<td>&gt;2</td>
<td>Research where multiple cohorts of participants responded to pre- and post-test versions of the STEBI-B, as they undertook a specified intervention.</td>
</tr>
<tr>
<td>2</td>
<td>Quasi Experimental pre/post</td>
<td>2</td>
<td>Research where a single cohort of participants provided STEBI-B data, both before and after, a specified period of time and/or undertaking a science intervention.</td>
</tr>
<tr>
<td>1.5</td>
<td>Equivalent groups</td>
<td>2</td>
<td>Research where pre- and post-intervention STEBI-B data were collected from separate groups and compared as equivalent data (Siter 2006)</td>
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Table 1.1 (continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Research type</th>
<th>Number of STEBI-B uses</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cross sectional</td>
<td>1</td>
<td>Research where the STEBI-B was administered to a group of pre-service teachers on one occasion to make comparisons with other variables.</td>
</tr>
<tr>
<td>0</td>
<td>Qualitative/alternate research purpose</td>
<td>Variable</td>
<td>There are two primary types of research that fall into this category: Research where the STEBI-B instrument was not used to provide statistical data, as originally intended by the seminal authors (Enochs and Riggs 1990). Examples include the use of STEBI-B items as the basis for interview questions (e.g., Tosun 2000) and the use of STEBI-B as an instrument for professional reflection (e.g., Lewthwaite et al. 2012). Research where the STEBI-B instrument was outlined in the methodology, but the subsequent STEBI-B data was not presented (e.g., Watters 2007).</td>
</tr>
</tbody>
</table>

focus. Table 1.2 below explains the selected innovative practices. The list of innovative practices provided as a part of the framework is by no means infallible. If anything, this list needs to be refined and modified in the future as science education research continues to progress.

The interventions were coded dichotomously as either including (1) or not including (0) each innovative practice. The judgement was based upon the author's thorough reading of the intervention descriptions, which were supplemented by the use of a search function to assess the use of key terms. An innovative practice did not have to be explicitly explained within an intervention to be classified as ‘included’, rather the practice had to be evident within the description based on the informed reading of the researcher. The quality and depth of innovative practices were not differentiated in this coding scheme.
<table>
<thead>
<tr>
<th>Innovative practice</th>
<th>Description</th>
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<tbody>
<tr>
<td>Constructivism</td>
<td>Learning that occurs when an individual constructs their knowledge through active participation (i.e. discussion) within a phenomenon or situation (Slavin 1991; Vygosky 1977)</td>
</tr>
<tr>
<td>Problem-based learning</td>
<td>Problem-based learning is a deep learning strategy that helps students to develop transferrable skills, which can be used in novel situations (Schmiel et al. 2006). Problem-based learning uses real-world problems as a starting point for the acquisition and integration of new knowledge into existing schemas (Azer 2001; Kahn and O’Rourke 2005)</td>
</tr>
<tr>
<td>Integration with other key learning areas (KLAs)</td>
<td>An approach to teaching where two disciplines, that are considered fundamentally separate, are integrated to create deep learning outcomes. For example, allowing students to collect and graph data is an example of a deep integration between mathematics and science</td>
</tr>
<tr>
<td>Mentoring</td>
<td>Mentoring is an emerging practice where pre-service teachers are paired with experienced teachers in order to focus on a particular discipline (e.g. Kenny 2010). The pre-service teachers observe experienced teachers and receive feedback on their own emerging teaching practice</td>
</tr>
<tr>
<td>Curriculum development</td>
<td>This term broadly encompasses teaching pedagogies and learning opportunities that accurately reflect the responsibilities and actions of the profession for which the students are being trained to enter. Within the context of this review this would include approaches such as allowing the pre-service teachers to create science units of work for classroom use</td>
</tr>
<tr>
<td>Inquiry learning</td>
<td>Inquiry learning allows participants to develop transferrable skills and knowledge to seek the information needed in order to achieve a task (Duran et al. 2009; Edelson et al. 1999). Open inquiry occurs when the participants have complete control over processes of inquiry. Guided inquiry occurs when some structure is provided to guide students towards a learning goal</td>
</tr>
<tr>
<td>In-subject practical experience</td>
<td>This occurs when the intervention is designed with embedded opportunities to teach science to students of the intended year levels</td>
</tr>
<tr>
<td>Links to practical experience blocks</td>
<td>Unlike ‘in subject practical experience’ this occurs when the student teachers are required to undertake some form of science teaching and reflect upon their experiences after they complete a specified tertiary science subject</td>
</tr>
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Table 1.2 (continued)

<table>
<thead>
<tr>
<th>Innovative practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative learning</td>
<td>Cooperative Learning occurs when students work together in separate, complementary roles to complete a task that would otherwise be impossible to complete individually</td>
</tr>
<tr>
<td>ICT instruction/incorporation</td>
<td>The students explicitly learn about the use of ICT in a way that is relevant to classroom teaching practice. For example, the use of Interactive Whiteboard Software for creating learning aids. Deep ICT instruction may be imbedded within subject assessment</td>
</tr>
<tr>
<td>Student centred investigation</td>
<td>These are investigations where the students assume the locus of control within the confines of the subject. Ideally, students should have control over all stages of the investigation, with the instructor acting in a facilitative role</td>
</tr>
<tr>
<td>Authentic tasks</td>
<td>In the tertiary science context, authentic tasks are those that are clearly related to the profession/career that the students are studying to enter. Examples may include developing units of work, practical experiences and researching student misconceptions</td>
</tr>
<tr>
<td>Nature of Science</td>
<td>The understanding that scientific knowledge is fluid and always subject to reasonable debate. Instruction in this area may orient the learner to the variety of scientific approaches beyond an experimental research design</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>A misconceptions based approach is a practice where the misconceptions of the students are identified and revealed to them. These misconceptions form the basis of the learning experiences delivered to the students</td>
</tr>
</tbody>
</table>

Using Effect Sizes to Evaluate the Interventions

The effect sizes of STEBI-B studies that included a tertiary science intervention targeting pre service teachers and used the STEBI-B at least twice in a pre/post-test design (i.e. a code 1.5 or greater on the research approaches) were collected and compared to determine which approaches correlated with the strong increases in the PSTE and STOE scores of the participants.

The calculated Cohen’s D Effect sizes were selected for research that utilised a single group of participants. However, for relevant research with multiple cohorts an average effect size was calculated to most accurately reflect the science teaching efficacy changes within the participants. For research with two cohorts, a mean was calculated. Within research that included three or more experimental groups, a statistical outlier was classified as an effect size of 0.5 higher or lower than the
closest ordinal effect size. When no outliers existed a mean was calculated. When an outlier was present, the median effect size (or mean of the median scores) was selected to represent the research. The final number of research papers and dissertations included in this review was 140.

Organisational Framework for the Analysis of the STEBI-B Literature

My initial conceptualisation of this STEBI-B review was to construct a funnel that systematically critiqued and eliminated research at a variety of levels until the reader was left with most exemplary research that utilised the instrument. In retrospect, such a conceptualisation is a vast oversimplification of a 25-year old body of literature that features contributions from 14 different nations. Simply put, no single funnel exists that can identify ‘the best’ research. The unique social, cultural and historical contexts that the research articles and dissertations reflect make definitive judgements and comparisons highly complex. I do not have the inclination or the expertise to attach value judgements to the 140 STEBI-B research items from a research design perspective. Instead, I chose to include comparisons in this paper in an objective and consistent fashion. Methodological groups, descriptive statistics, subscale analyses and Cohen’s D effect sizes are presented to meet the aims of this paper. As an outsider, I am not privy to the complex interactions that have occurred amongst the reported innovative practices and the subsequent STEB changes of participants. Thus, I now conceptualise my role as organising and critiquing the research without making definitive statements on methodological quality and providing a point of objective comparison of ‘innovative’ science interventions. It is hoped that the structure presented allows the reader to make his or her own judgements based on his or her unique perspectives.

The organisation and presentation of 140 pieces of individual research demands a definitive structure. Content and purpose cannot be divorced from methodology in a single piece of research. This is the primary reason why this Springer Brief reviews research designs and assesses science interventions. A separation of these elements would leave the story incomplete. ‘Research designs’ has been selected as the core principle within the organisational framework. The methodological choices of the researchers provide a clear and universal lens through which research can be grouped and discussed. The focus on methodology also helps to enhance the narrative of the paper as the research presented builds towards the evaluative focus of the latter half of the paper. An objective comparison is achieved as dichotomous coding of innovative practices is reconciled with STEB effect sizes. Research designs and innovative practice summaries are provided to discuss emergent trends. No conclusions can be drawn in either domain.
Figure 1.2 shows the STEBI-B review framework. Blue has been used for the research designs review and Red has been used for the more complex innovations comparison. The blue inverted triangle to the right shows how all research articles have been grouped and separated based on the number of STEBI-B administrations. The research designs at the top of the triangle generally used the STEBI-B on fewer occasions than those at the bottom of the triangle. Once categorised and discussed an individual paper is removed from future sections research design analysis. This is represented by the funnel shape. The red triangle represents a separate analysis of research items that use the STEBI-B at least twice (pre/post test) to evaluate a science intervention. The two red arrows connecting the red triangle to the Venn diagram shows the information that was extracted from the relevant articles to gain a broader understanding of the effects of the different “innovative” practices used within science interventions. The complexity of the research domain is shown by the red arrow that passes through “PSTE and STOE subscale use” before the “PSTE and STOE Effect sizes (Cohen’s D)”. Research papers needed to employ the recognised subscales using accepted statistical approaches for comparisons to be made. The red circle on the left of the Venn diagram represents the reported innovative practices. The red circle on the right of the Venn diagram represents the reported PSTE and STOE Effect sizes. The intersection of the Venn diagram represents the connection between reported innovative practices and STEB Effect sizes. The dotted arrows and the question mark show the
hypothesized, but unknowable, relationship between these variables. Indeed this represents a limitation of the research, as the researcher cannot know the contextual interactions that may have influenced the relationship between these variables.

Findings

The findings for this review are presented in two sections. Firstly, an overview of the use of the STEBI-B instrument within research designs will be presented. This section will be broken down into research designs and subscale usage. Secondly, a comparison of the effects of the different science interventions reported in the STEBI-B literature will be made. This will be achieved by outlining the use of the different innovative practices and then comparing the same papers in terms of PSTE and STOE effect sizes.

STEBI-B Research Designs

The following subsections will present and discuss trends amongst the different research designs employed within the STEBI-B body of literature. At the end of each section the discussed papers will be removed from the analysis. This adheres to the conceptual framework outlined above as the funnel focuses on STEBI-B administrations to lead into the evaluation of innovative practices further along in the paper. After repeats were removed, a total of 140 articles were included in this section of the analysis.

Qualitative and Alternate Research Approaches (0)

Much of the research coded at this level was limited by small sample sizes (Englehart 2008; Lewthwaite et al. 2012; Peters-Burton and Hiller 2013; Soprano and Yang 2013). Englehart’s (2008) deep case study approach suggests that inquiry based curriculum support materials can improve the science teaching efficacy, pedagogical content knowledge and inquiry teaching practices of pre-service early childhood teachers. However, due to small number of participants (3) the results cannot be generalised to alternate contexts and the statistics cannot be calculated for comparison. Similarly, the research of Peters-Burton and Hiller (2013) was marred by a low number of participants. The six participants responded to the STEBI-B instrument as a complement to interview data. The findings showed that the pre-service teachers placed a stronger emphasis on how ‘fun’ a science lesson could be rather than the science concepts being delivered, even when their students directly requested the latter. Soprano and Yang (2013) opted to use the
STEIBI-B instrument within a deep, action research paradigm. A single pre-service teacher responded to 13 items on the PSTE subscale and each item was analysed independently.

A number of research projects featured the STEIBI-B in a qualitative context (Lewthwaite et al. 2012; Tosun 2000; Watters 2007), thus limiting the relevance in this review. Tosun (2000) used the STEIBI-B items to design a series of semi-structured interview questions and found that 44 pre-service elementary teachers had overwhelmingly negative science teaching efficacy. In an attempt to assess the effect of Nature of Science (NOS) instruction, Lewthwaite et al. (2012) used the STEIBI-B to aid the personal science teaching reflection of a single pre-service teacher. The presentation of STEIBI-B data was another issue that arose in this level of coding. Watters (2007) outlines a strong longitudinal, experimental research design employing a mixed methods approach. However, the STEIBI-B data were not presented clearly or consistently within the results. The data could not be classified as transparent as no standard descriptive statistics were provided to allow for cross checking. Although Watters (2007) reported that the intervention produced positive gains within the 360 participants, the aforementioned issues with the results have prevented this study from being included in further analyses.

A recent trend in the STEIBI-B literature has been the modification of the STEIBI-B instrument for more specific, alternative contexts. Such modifications of the original STEIBI-B instrument fundamentally change the targeted constructs, thus the studies have been coded as ‘alternate approaches’. Wilson (2012) modified the STEIBI-B instrument to focus on pre-service teachers’ conceptualisations of sustainability. The participants reported high self efficacy in their capacity to deliver education for sustainability with many believing that they would openly encourage inquiry questions for which they did not have an immediate answer. In a similar focus area, Richardson et al. (2014) chose to adapt the STEIBI-B instrument to explore environmental education self efficacy. The new instrument was used across both a science content subject and a science methods subject. The participants’ personal efficacy increased in the content course but decreased in the methods course. The outcome expectancies showed no change and were subsequently dismissed. Other STEIBI-B modications were based around: technology efficacy (Ting and Albion 2014); Astronomy concepts (Ivey et al. 2015); Inquiry science teaching (Avery and Meyer 2012); and the need to adapt to new cultural contexts (Park 1996). These alternate research pathways may be a signpost for the future of the STEIBI-B body of literature. A total of 24 research papers were either classified as qualitative or deemed to be employing an alternate research approach. After these studies were eliminated, 116 studies were included in the next step of the analysis.

**Cross Sectional Research Designs (1)**

Research with a cross-sectional usage of the STEIBI-B instrument has allowed the construct of science teaching efficacy to be linked to a broad array of variables.
Variables such as classroom management beliefs (Gencer and Çakiroğlu 2007), epistemological views (Sunger 2007; Yılmaz-Tuzun and Topcu 2008) and science content knowledge (Mashnad 2008; Sarıkaya et al. 2005) have all been analysed in relation to STEBI-B data. More specifically, Gencer and Çakiroğlu (2007) utilised a robust sample of 584 preservice science teachers to identify a negative correlation between PSTE and STOE scores and the use of teacher-centred, interventionist classroom management strategies. Sunger (2007) found that both elementary teachers and secondary science teachers expressed moderately high STEBs and viewed the acquisition of knowledge to be underpinned by non-linear reasoning, repeated learning and continued inquiry. Yılmaz-Tuzun and Topcu (2008) explored epistemological views in relation to preservice teacher STEBs in greater depth. Multiple regression analysis showed that preservice teachers with higher STEB scores were less likely to believe that their students’ capacity for learning is a fixed, unchanging characteristic. Curiously, some evidence was presented that showed higher STOE scores were related to beliefs that science is composed of fixed, unchanged knowledge. Sarıkaya et al. (2005) employed Multiple Regression Correlation Analyses to determine the extent to which STEBs accounted for the variance in 750 Turkish preservice teachers’ science knowledge scores. Results showed that PSTE accounted for 40% of the variance, whereas STOE accounted for just 4% of the variance. Contrariwise, Mashnad (2008) found no link between the science content knowledge of 91 preservice teachers and their STEBs. One interpretation was that the participants displayed a limited awareness of the alternative science conceptions they continued to hold as adult learners.

Comparisons between mathematics and science views are prominent within the STEBI-B literature (Bursal and Paznakos 2006; Bursal 2010; Wenner 2001). Bursal (2010) found that despite a strong positive correlation between personal mathematics teaching efficacy and personal science teaching efficacy, the respondents had much higher mathematics teaching efficacy scores. Earlier research (Bursal and Paznakos 2006) further strengthens the connection between science and mathematics attitudes amongst pre-service teachers. The data indicated that there was a negative correlation between reported science teaching efficacy and mathematics anxiety.

Cross sectional STEBI-B administration has been used to analyse science teaching efficacy in relation to scientific misconceptions (Schoon and Boone 1998; Tekkaya et al. 2004). A sample of over 600 pre-service elementary teachers revealed that low science teaching efficacy beliefs covaried with reported fundamental science misconceptions (Schoon and Boone 1998). The key misconceptions reported were based on planets, dinosaurs and electricity. Evidently, fundamental gaps in science content knowledge serve as barriers to the development of science teaching efficacy in pre-service teachers. Yet, Tekkaya et al. (2004) found that this covariant relationship does not extend to the secondary teaching domain. A group of 299 pre-service science teachers reported confidence in science teaching despite holding misconceptions concerning fundamental science concepts.

A significant portion of the body of literature employed the STEBI-B to compare the science teaching efficacy beliefs of different sub-groups of pre-service
teachers (Arighbabu and Oludipe 2010; Çakırdağ et al. 2005; Newsome 2003; Rogers and Watters 2002; Wenner 2001). Wenner (2001) analysed response rates to the different items on the STEBI-B scale to compare the science teaching confidence and accountability perceptions of pre-service and in-service teachers. Perhaps unsurprisingly, the in-service teachers reported higher science teaching confidence. Nevertheless, pre-service teachers appeared more receptive to student questioning in science. In terms of accountability, only 53% of pre-service teachers believed that teaching was responsible for student achievement. Newsome (2003) compared the STEBs of various sub-groups of pre-service teachers. In this study, pre-service teachers who completed in-school professional development held higher PSTE scores than their counterparts in traditional tertiary courses. In line with familiar themes in the literature, student teaching setting, academic level, academic major or area of science concentration did not affect the STOE scores.

Many of the STEBI-B research items emerging from Turkey employ the STEBI-B in cross sectional ways (Bahtıvan and Kapucu 2014; Kahraman et al. 2014; Olgan et al. 2014; Serin and Bayraktar 2014). Bahçıvan and Kapucu (2014) assessed the PSTE scores of 379 pre-service teachers in relation to their conceptions of science learning. The results indicated that investigative constructs were positive indicators of participants’ PSTE scores. Curiously, ‘application of skills’ was a negative predictor of PSTE, suggesting that the participants were not yet comfortable shifting from theoretical understandings to practical science engagement as teachers. Olgan et al. (2014) delved into the issues with the STOE sub-scale by determining how the construct is influenced by other variables. The results showed that PSTE and justification of science knowledge were sound predictors of STOE scores. Curiously, epistemological beliefs, attitudes toward science teaching and scientific content knowledge did not have significant influences upon the STOE scores of the 379 pre-service teachers. Serin and Bayraktar (2014) researched the relationship between pre-service teachers’ beliefs about locus of control and their science teaching efficacy beliefs. The results showed that participants with internal locus of control beliefs had higher science teaching efficacy than their counterparts with external locus of control beliefs. A total of 32 research items, cited within this review, adopted the STEBI-B in a cross sectional way. After these studies were eliminated, the pool of research papers decreased to 84.

**Research with Equivalent Groups (1.5)**

The research presented within this section of the analysis is similar to the ‘cross sectional’ research in that each participant is only exposed to the STEBI-B instrument on one occasion. However, the following authors have attempted to circumvent the lack of comparative opportunities within a cross sectional approach by comparing the STEBs of separate, but equivalent, groups that differ on one or more key variables. The average number of participants in research using equivalent groupings is 241 (Aydın and Boz 2010; Bayraktar 2011; King and Wiseman 2001;
Luera and Otto 2005; Veldhuizen et al. 2014; Wenner 1995). This is a mean of over 100 participants higher than the mean of 125 participants shown in the 129 articles that provided clear information on participant numbers. The mean number of participants for single cohort pre/post designs is 67. It appears as though the researchers using the STEBI-B in an equivalent groups design may be partially overcoming the lack of pre/post case matching with significantly higher numbers of participants.

Equivalent group designs are often used to research science education programs (Wenner 1995; Veldhuizen et al. 2014). Wenner (1995) used an “equivalent groups” design to assess the effectiveness of changes to a science program implemented over two years. The first sets of data were taken from pre-service teachers in 1992 prior to an increase in the number of science subjects. The follow-up data set was taken from a separate cohort in 1994, after the core changes had occurred. Results indicated that the second group, who experienced the changes, reported significantly higher PSTE scores than the 1992 group. Similarly, Veldhuizen and others (2014) compared the STEBs of multiple pre-service teacher cohorts between two universities in order to determine the effect of increased mandatory science subjects. A curious finding was that first year pre-service teachers who experienced a science content course reported higher PSTE scores than those who partook in a science methods course. However, by the second year of study this difference had disappeared.

Equivalent groupings can be used to evaluate preparatory teacher education courses rather than single science subjects (Aydin and Boz 2010; Bayraktar 2011; Luera and Otto 2005). Luera and Otto (2005) focused on the impact of the number of science subjects offered on the science-teaching efficacy of pre-service teachers. A group of 20 pre-service teachers who completed the institution’s three science subjects were compared to a baseline group of 101 pre-service teachers who had not begun their science studies. Experience with three science subjects carried with higher PSTE scores (Cohen’s D = 0.857). Curiously, there was no significant difference between the groups on the STOE subscale. A similar design was used in a Turkish context to assess the holistic effect of an undergraduate degree on the STEBs of pre-service teachers (Bayraktar 2011). A comparison between the PSTE scores of first and fourth year students suggested that those who had undertaken the course curriculum experienced moderate gains in their personal science teaching efficacy beliefs. Additional research has compared first and fourth year pre-service teachers for a broader programmatic focus (Aydin and Boz 2010). Results showed that the fourth years had higher PSTE scores but very similar STOE scores to their first year counterparts. After the six ‘equivalent groups’ articles were removed from the analysis, 78 remained for the following section.

**Quasi Experimental Designs with a Single Cohort (2)**

The quasi-experimental research items almost solely utilised the STEBI-B instrument to explore covariant relationships between participation in different science
interventions and STEB changes from pre- to post-occasions of testing. To prevent
duplication, the findings of papers at this level will be explored in greater detail
later in this chapter. Pre- and post-test administrations of the STEBI-B were used
to assess science interventions that included an array of pedagogies including:
constructivism (Bleicher and Lindgren 2005); field experiences (Plourde 2002;
Sindel 2010; Wagler 2011); inquiry learning (Shroyer et al. 1996); problem-based
learning (Wingfield and Ramsey 1999) and misconception targeting (Jabot 2002).
Templeton (2007) reported on the science teaching efficacy development of a
group of pre-service teachers as they employed constructivist approaches to design
science curriculum for a local museum. Setting aside the small sample of 14, the
participants displayed a 2-sigma effect size growth in their reported PSTE scores
and close to 1-sigma growth on the STOE subscale. A science methods course
that afforded participants the chance to teach science, record their science lessons
and reflect on their science teaching practice, lead to similar effect size growth in
participants’ STOE scores (Naidoo 2013). However, such improvements to pre-
service teachers’ beliefs about the capacity of science teaching to improve student-
learning outcomes appear to be outliers within the STEBI-B literature base.

Much of the research at this level of the analysis reports stagnation, and in some
instances slight declines in the science-teaching outcome expectancies of pre-ser-
sive teachers (Bursul 2008; Hudson 2004; Plourde 2002; Watters and Gins 1999;
Yılmaz and Cavas 2008). Plourde (2002) described a science methods course that
used constructivist approaches to prepare participants for an imbedded practical
science teaching experience. The 59 pre-service teachers showed stagnated PSTE
scores and moderate effect size declines in their STOE scores. The author atributed
these declines to contextual in-school factors, such as; insufficient time, lim-
ited resources and the absence of collegial support, which are commonly cited
within the literature (Goodrum et al. 2001; Goodrum and Rennie 2007; Griffith and
Scharmann 2008). The stagnation of the PSTE scores was ascribed to participants’
negative experiences as students themselves. Later research suggests that Plourde’s
interpretations may be accurate (Yılmaz and Cavas 2008). The STEB’s of 185 pre-
service were unaffected by in-school teaching placements, which may be another
piece of evidence of the aforementioned issues with science education.

The depth and quality of research using the single cohort, pre-post test design
has continued to improve in recent years. Since 2014, 10 studies have been pub-
lished to make meaningful contributions to the existing STEBI-B literature. The
pedagogical base is expanding beyond the limitations of the conceptual framework
in this paper, making it difficult to summarise the innovative practices in succinct
ways. Emerging science interventions include: Virtual worlds (Bautista and Boone
2015); Cognitive-apprenticeship based instruction (Cooper 2015); Community
Links (Yang et al. 2014); and increasingly deep practical science teaching expe-
riences (Cartwright and Atwood 2014; Flores 2015). Bautista and Boone (2015)
found that participation in a mixed reality learning environment covared with
significant increases in the PSTE and STOE scores of 62 pre-service teach-
ers. Controlled pedagogical mastery, emotional arousal and self-modelling were
identified as contributing factors that would otherwise be unavailable in more
traditional science teaching approaches. Yang et al. (2014) found that pre-service teachers showed a large effect size gain in their PSTE scores after completing a content and pedagogy-based STEM course. The researchers and participants attributed these gains to the opportunities for service learning afforded by two community partner organisations. A total of 46 pieces of STEBI-B research used a quasi-experimental design with a single cohort. After these studies were removed, 32 remained eligible in the next step of the analysis.

**Quasi Experimental Designs with Multiple Cohorts (2.5)**

Quasi-experimental research with multiple cohorts affords researchers with unique opportunities to assess interventions across different iterations over time. Ford and others (2012) collected data from three separate cohorts from 2006 to 2008, to assess the relationship between pre-service teachers’ participation in science courses focusing on inquiry-learning and problem-based learning, and their STEBs. The science course addressed three key science content areas (Physical Science, Biology and Earth Science) in conjunction with science curriculum through inquiry questions, assessment tasks and guided laboratories. Two of the three cohorts had strong PSTE growth. The 2007 cohort showed small to moderate PSTE growth (Cohen’s $d = 0.3$). This finding is in considerable contrast to the 2006 (Cohen’s $d = 0.94$) and 2008 (Cohen’s $d = 1.1$). This difference between the cohorts was not addressed by the authors. Conversely, none of the cohorts showed any significant change in their outcome expectancies. There were no trends over time within this study. Morrell and Carroll (2003) found that the fourth iteration of an inquiry science methods course lead to much higher growth in the personal science teaching efficacy of participants than the previous three. The science and mathematics methods course used extended field experiences (12 h per week) to provide students with opportunities to teach science lessons which they had developed. The PSTE effect size reported in 1997, 1997 and 1999 were 0.206, 0.338 and 0.2 respectively. For the science course offering in 2000, the reported PSTE effect size rose to 0.95. This raises a ‘why’ question that needs to be answered. Sasser (2014) used a multiple cohorts design to analyse Problem-Based Learning (PBL) with unparalleled depth. Rather than retracing previous trails by assessing the educational impact of PBL, Sasser (2014) explored the structure required for effective implementation. Two cohorts of pre-service teachers were given the same problem-based learning scenario. One cohort was given structural support, whereas the other received no support as they engaged in an open-ended experience. Curiously, there was no significant difference in the science teaching efficacy beliefs between the cohorts. The additional structure did seem to help students to increase their science content knowledge.

An opportunity is being missed with the use of quasi-experimental research designs using multiple cohorts across multiple iterations of a science subject. The increased sample sizes and repeated STEBI-B administrations strengthen the
argument for covariance between the key variables, but deeper narratives can be explored. Certainly, a focus on how the changes that are made to science interventions and the subsequent effects of those changes on the STEBs of pre-service teachers represents a deeper, fresher path for future research in this area. There were 12 studies that supplemented quasi experimental with repeated implementations across multiple cohorts. After these studies were removed, 20 were assessed in the next stage of analysis.

Longitudinal Quasi-Experimental Research Designs (3)

Much of the research coded at this level assesses the durability of STEB gains made during a pre- and post-test, quasi-experimental investigation (Ginns et al. 1995; Hechter 2008; Palmer 2006a, b; Richardson and Liang 2008). Palmer (2006a) found the considerable STEB improvements that students experienced as they participated in an innovative science methods course (modelling, inquiry, cooperative learning) remained durable for up to nine months after the course had been completed. Opportunities for mastery experiences were crucial to the consolidation of the preservice teachers’ STEBs as their practical science teaching experiences provided tangible evidence of their emerging abilities to both engage students and assist them to meet science learning objectives. Richardson and Liang (2008) chose to administer the STEBI-B in the first week of the second science subject to assess the durability of the efficacious changes that occurred within their first science subject. Not only were the STEB changes durable in the absence of the inquiry-learning science subject, the participants displayed small increases during this period. Ginns and others (1995) took a more holistic approach as they examined STEBs in relation to an entire teacher education program. They found that the STEBs of pre-service teachers did not improve as they completed the teacher education program. Hechter (2008) used a longitudinal framework to explore pre-service teachers’ reflections on their educational experiences within a science methods course, rather than to investigate durability. After a delay period, the pre-service teachers were asked to respond to the STEBI-B instrument based on how they felt about science teaching prior to undertaking the science methods course. Upon reflection, their retrospective pre-test scores were much lower than the original pre-test scores. Clearly, they valued the science methods subject after experiencing it in full. There were 8 research articles remaining after the 12 longitudinal pieces of research were removed.

Experimental Research Designs (4)

The remaining 8 research articles used experimental research designs. Schramm and Oril Hampton (1995) used a robust experimental design with two cohort
groups to assess the impact of a science methods course involving hands-on investigation and cooperative learning. The heterogeneous cooperative learning groups did not show higher science teaching efficacy beliefs than those in the control group. McDonough and Matkins (2010) created an experimental design, strengthened by repeated measures, by collecting data from different institutions over two years. Despite statistical outliers, the results indicated that imbedding science into practical teaching experiences causes larger PSTE increases. Logerwell (2009) showed that problem based learning strategies represent a viable way of increasing pre-service teachers’ outcome expectancy beliefs. The study employed two control groups and an experimental group over a 2-week summer science teaching experience.

In a creative solution to ethical issues at the tertiary level, Ebrahim (2012) used a cohort of pre-service teachers enrolled in a practical placement course, with no science component, as a control group. Those who participated in the science methods course displayed moderate STEB growth, whereas the control group showed no STEB change. Thus, the researcher can make the claim that the curriculum design and science teaching experiences caused the increased science-teaching efficacy reported by participants. A similar science methods course showed increased STEBs in the experimental group (Bhattacharyya et al. 2009). Conversely, the control group showed small declines. However, the generalisability of the research is limited by both the small sample size and the lack of subscale differentiation. The following section will describe the use of the PSTE and STOE subscales within the STEBI-B literature.

**The PSTE and STOE Subscales Within the STEBI-B Literature**

There were 117 articles that provided sufficient information to allow for the subscale use to be analysed. Within the selected articles, there is some inconsistency amongst the usage of the PSTE and STOE subscales, despite the conceptual separation of both subscales (Bleicher 2004; Enochs and Riggs 1990). Simply blending both constructs together does not accommodate the complexity of the targeted constructs and yet 16 pieces of research have done just that. This blending can take the form of merged STEB scores (e.g. Kahrman et al. 2014) or single item analyses (e.g. Urban-Woldron 2014). Such errors may be more prominent in cross-disciplinary educational comparisons where the researchers are perhaps not as familiar with the STEBI-B instrument (Bursal and Paznokas 2006; Săcăces et al. 2012). Conversely, ignorance cannot be blamed in research where the subscales are not differentiated within the results after the author(s) describe them earlier in their writing (e.g. Slater et al. 2008).

Discounting the research with blended subscales, nearly a quarter of all analysed papers did not measure the STOE subscale. Of the 104 papers that formally
measured the PSTE subscale, 14 of these did not measure the STOE subscale. The choice to ignore the STOE subscale in favour of the PSTE subscale is becoming more prominent as time passes with 79% of the research in this category being published after 2007. The implications of the decline in STOE usage will be unpacked in the discussion.

In most studies the PSTE scores of the participants were greater than their STOE scores on all occasions of testing. In total, there were 83 research articles that clearly presented comparable data for both subscales on at least one testing occasion. The mean scores of the PSTE were higher than the STOE on all testing occasions in 92.7% of these papers. Thus, only three studies exist where the STOE was recorded as greater than the PSTE at any point (e.g. Baymktar 2011). This trend implies that despite feeling confident in their own abilities, many pre-service teachers are not as certain about the effectiveness of science teaching in general. This is unpacked in greater detail in the discussion section.

It appears harder to produce growth within the STOE subscale in comparison to the PSTE subscale. There were 58 papers that allowed for growth comparisons between the subscales because they met the following conditions; the STEBI-B was used at least twice; and the appropriate descriptive statistics were presented clearly, 84.5% of these papers showed higher growth on the PSTE subscale. Nevertheless, there is some evidence of positive change emerging from the body of literature as 6 of the 7 research items that display greater STOE growth were published in 2009 and beyond. Hopefully, this is a sign of development stemming from reflection upon earlier research rather than an anomaly. The next section will explore the innovative practices used within science interventions.

**Innovative Practices Within the Science Interventions**

A total of 91 STEBI-B articles included a science intervention as part of the research design. There were 8 articles which did not describe the intervention in sufficient detail for the dichotomous coding of innovative practices. Each of the remaining 83 articles was coded as either employing or not employing each of the 14 identified innovative practices. Figure 1.3 presents the number of research items that used each of the innovative practices. Non Sequenced Content was coded to reflect a more traditional approach to science content course design. There is strong variation in the innovative practices employed within analysed science interventions. The innovative practices are not mutually exclusive of one another and in many instances multiple practices have been amalgamated into complex science education designs.

The most common pedagogical inclusions were curriculum development (43.4%), inquiry learning (51.8%) and in-subject practical experience (43.4%). The prominence of these approaches suggests that the interventions are being thoughtfully designed to suit the purpose of pre-service science education (i.e. producing elementary science teachers). Unsurprisingly, constructivism (34.9%)
was also cited frequently within the literature. However, despite constructivism being mentioned frequently as an underlying principle it is seldom described in an actionable way. Simply put, the readers need to know how opportunities for constructivist learning have been provided within intervention descriptions. It is not uncommon for educational concepts, such as constructivism, to be broadly outlined without supporting information relating to pedagogical structure (e.g. Plourde 2002). This has led to the researcher to conclude that constructivism is primarily being included in a shallow, tokenistic fashion. This interpretation is supported by the lack of detail and scaffolding that is often evident in cooperative learning inclusions. This is certainly not a criticism of researchers, many of whom are responding to the constraints of their chosen mediums. More broadly speaking, the requirement for detailed pedagogical descriptions represents a need for a holistic shift in the focus of science education research to processes/interventions in combination with findings.

There appear to be themes within the interventions that could be construed as problematic. Firstly, the delivery of varying science concepts on a weekly basis was a frequent theme in this analysis (28.9 %). Such isolated, content focused learning experiences conflict directly with the more integrated, student centred and profession focused interventions that covary with positive outcomes for students. However, it should be noted that the 24 interventions employing the weekly content change strategy generally have supplementary innovative pedagogies in place. Weekly content change generally involves new areas of content focus each week. Week one may focus on biology, week two may focus on geology, week three may focus on chemistry and so forth. It may be challenging, although not impossible, to make rich connections between different content areas in a single semester. Ford and others (2012) were able to overcome the issues of this approach by limiting the semester to four content areas which linked with ongoing inquiry and problem-based learning approaches. The mean number of innovations
of this group (3.16) is almost the same as the entire group of analysed interventions (3.23). Secondly, ICT instruction (6%), rich tasks (11%) and mentoring (12.6%) are underrepresented within the literature. The absence of mentoring is particularly disconcerting as this may represent a divide between pre-service and in-service teachers. Such a divide could diminish the positive long term effects of tertiary science education programs. The following section will explore the PSTE and STOE effect sizes reportedly produced by these science interventions.

**The PSTE and STOE Effect Sizes Produced by Science Interventions**

Prior to analysing the effect sizes for the PSTE and STOE subscales, the studies with less than 21 participants were removed from the analysis. This prevents the potentially inaccurate skewing of data and should allow for a relatively normal distribution of STEBI-B scores within the included research items. Figure 1.4 below shows the distribution of effect sizes reported on both the PSTE and STOE subscales. The red lines show the insignificant, small, moderate, large and very large effect size ranges. It should be noted that despite a slight negative skew, the STOE effect sizes are also normally distributed. The PSTE scores are generally higher with a positive skew as all but one of the very large ES gains were reported on this subscale. The Kurtosis scores of the PSTE and STOE effect size data sets show further subscale differences. The PSTE (−0.272) Kurtosis is close to zero, suggesting a relatively normal distribution curve. In comparison, the STOE Kurtosis (0.723) shows a flatter distribution of scores spread further from the mean. This would appear to reflect both the inconsistent measurement and frequent stagnation of the STOE subscale.

![PSTE and STOE distribution histogram](image)

**Fig. 1.4** PSTE and STOE distribution histogram
Statistical analysis indicates that there is a substantial difference between the PSTE and STOE subscales in terms of mean effect size produced within the body of literature. Table 1.3 presents the descriptive statistics for the PSTE and STOE effect sizes. The mean effect size produced on the STOE subscale is moderate (0.43) and only approximately half of that shown on the PSTE subscale (0.83). This trend is representative of the wider body of STEBI-B literature as PSTE growth is almost always higher than STOE growth. This is evident in 84.5% of relevant cases. There were 9 research items included in the effect size analyses which did not measure the STOE subscale, despite correctly utilising the PSTE subscale. There may be lower effect sizes on the subscale that are not being reported within the literature.

Even though there are substantial statistical differences between the mean scores and effect sizes on both the PSTE and STOE subscales, a statistically significant correlation exists between these science efficacy measures. Table 1.4 shows the output from the correlation analysis conducted on the mean PSTE and STOE effect sizes. The correlation analysis shows that there is a statistically significant moderate-to-strong correlation (Pearson’s R = 0.628) between the PSTE and STOE effect sizes. These findings indicate that the STOE needs to be considered alongside PSTE rather than dismissed for science teacher education. The issues with the STOE subscale will be unpacked further on in the discussion section of this chapter. The following paragraphs will rank the PSTE and STOE effect sizes within the literature and unpack the pedagogical themes.

The variation in innovative practices employed within the top science interventions in terms of PSTE effect sizes indicates that there is no ‘simple’ solution to improving the science outcomes of pre-service elementary teachers. Table 1.5 ranks the top research pieces on PSTE effect size changes and lists the identified innovative practices. The author recognises that the innovative practices listed may be limited by the framework. It is advised that the reader refer to the original articles for more accurate information. The most recurrent innovative

<table>
<thead>
<tr>
<th>Table 1.3 Descriptive statistics for PSTE and STOE effect sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>MeanPSTE</td>
</tr>
<tr>
<td>MeanSTOE</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Table 1.4 Correlation analysis for PSTE and STOE effect sizes</th>
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</thead>
<tbody>
<tr>
<td><strong>Pearson correlation</strong></td>
</tr>
<tr>
<td>MeanPSTE</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>MeanSTOE</td>
</tr>
<tr>
<td>N</td>
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</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed)
Table 1.5  Top 10 PSTE: effect sizes

<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Innovative practices</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Jabot</td>
<td>Curriculum development, links to professional experience blocks and alternative conception targeting</td>
<td>2.0</td>
</tr>
<tr>
<td>2015</td>
<td>Cooper</td>
<td>Mentoring, curriculum development, in-subject practical experience</td>
<td>1.93</td>
</tr>
<tr>
<td>2006a</td>
<td>Palmer</td>
<td>Cooperative learning, student-centred investigation</td>
<td>1.87</td>
</tr>
<tr>
<td>2011</td>
<td>Bautista</td>
<td>Integration with other KLAs, inquiry learning, in-subject practical experience, link to professional experience blocks, nature of science focus, alternative conception targeting</td>
<td>1.83</td>
</tr>
<tr>
<td>2010</td>
<td>Swars and Dooley</td>
<td>Mentoring, curriculum development, inquiry learning, in-subject practical experience, links to professional experience blocks, student-centred investigation</td>
<td>1.67</td>
</tr>
<tr>
<td>2015</td>
<td>Flores</td>
<td>Curriculum development, link to professional experience blocks, cooperative learning</td>
<td>1.59</td>
</tr>
<tr>
<td>2009</td>
<td>Bleicher</td>
<td>Constructivism, curriculum development, cooperative learning</td>
<td>1.58</td>
</tr>
<tr>
<td>2009</td>
<td>Logerwell</td>
<td>Problem-based learning, curriculum development, inquiry learning, in-subject practical experience</td>
<td>1.44</td>
</tr>
<tr>
<td>2014</td>
<td>Yang et al.</td>
<td>Constructivism, integration with other KLAs, inquiry learning, in-subject practical experience, cooperative learning</td>
<td>1.3</td>
</tr>
<tr>
<td>2012</td>
<td>Brower</td>
<td>In-subject practical experience</td>
<td>1.27</td>
</tr>
</tbody>
</table>

practices amongst these 10 research items were in-subject practical experience (6), inquiry learning (5) and curriculum development (5). Of interest was the limited integration of misconception targeting (1) and nature of science teaching (1) amongst the PSTE top 10. The mean number of interventions within this group (3.6) was slightly larger than the mean produced by the entire group of analysed interventions (3.2).

Jabot’s (2002) science intervention may be a viable solution to the 2-Sigma problem (Bloom 1984) in relation to the PSTE of pre-service elementary teachers. A total of 24 pre-service teachers participated in a reflective, misconception based intervention. The students were required to develop a science unit of work that aimed to redress specific misconceptions held by elementary students. The intervention culminated in a ‘Teaching Participation’ practical experience where the pre-service teachers implemented their units of work to students of the appropriate age level. More generally, practical science teaching experiences seem to be related to larger PSTE gains (Bautista 2011; Brower 2012; Cantrell 2003; Logerwell 2009).

Complex science interventions with multiple innovative practices co vary positively with growth on the PSTE scale (Bautista 2011). The misconception targeting and practical experience elements were supplemented with opportunities for
the participants to observe the science teaching of accomplished teachers. Science teaching dvds, practical experience, science teaching observations and tutor modelling were used to deliver vicarious learning opportunities to pre-service primary teachers. This type of sophisticated pedagogical design would require strong inter-faculty relationships within teacher education programs and collaborative partnerships with elementary schools. Indeed, broad reform at a program level covaries with the improved science teaching efficacy beliefs of pre-service teachers (Wenner 1995). Given the declining state of elementary science education, in nations such as Australia, stemming from diminished curriculum time (Angus et al. 2004; Goodrum et al. 2001; Goodrum and Rennie 2007; Tytler 2007; Tytler et al. 2009) it would be challenging to implement similar vicarious experiences within the Australian tertiary context. Nevertheless, vicarious learning experiences could be used to improve stagnant STOEs. The following paragraphs rank and discuss the stronger research in terms of STOE outcomes for participants.

Many of the interventions, that produced high STOE effect sizes, showed deep pedagogical consideration through the use of multiple innovative practices. In fact, the top ranked STOE science interventions employed an average of 4.6 innovative practices. Table 1.6 ranks the top 10 research items on STOE effect size. Amongst these research items, cooperative learning (6), professional relevance (6), inquiry learning (6) and in-subject practical experience (6) were the most frequently used innovative practices. The biggest change from the PSTE items was the emergence of both cooperative learning approaches (6) and student centred investigation (4). An interpretation of this could be that cooperative learning extends a participant’s focus beyond the immediate self by allowing for meaningful collaboration with other prospective teachers, thus affording the necessary broader experiential learning necessary to affect change on the STOE subscale.

Curiously, two of the highest STOE performing articles chose to ‘simplify’ their educational designs to allow for a deep implementation of the chosen innovations (Ozdelek and Bulunuz 2009; Palmer 2006a). Ozdelek and Bulunuz (2009) reported on a traditional ‘weekly topics’, with content variations, approach to tertiary science education. The different content areas were supplemented with inquiry-based background research and ‘hands-on’ investigations. Palmer (2006a) employed a similar approach with the student-centred delivery of content pitched at the elementary level. Although less ‘academically rigorous’ the STEBI-B data indicates that these approaches help to alleviate the effects of pre-service teachers’ detrimental science experiences and negative attitudes to science by presenting the subject in a more accessible, engaging and professionally appropriate manner.

Deeply drilled, complementary science subjects within a tertiary education program can produce significant and durable growth in the STOEs of pre-service elementary teachers (Cross 2010; Dechan 2013). The first year science subject used Astronomy content to drive a misconception-based, inquiry based approach where the pre-service teachers were required to develop their Pedagogical Content Knowledge (Cross 2010). The second science subject implemented a collaborative, PBL scenario that afforded the pre-service teachers the opportunity to engage in a professional environment while developing their knowledge of the
Table 1.6 Top 10 STOE effect sizes

<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Innovative practices</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Jabot</td>
<td>Curriculum development, links to professional experience blocks and alternative conception targeting</td>
<td>1.54</td>
</tr>
<tr>
<td>2015</td>
<td>Cooper</td>
<td>Mentoring, curriculum development, in-subject practical experience</td>
<td>1.13</td>
</tr>
<tr>
<td>2000</td>
<td>Ozdelić and Bulumuz</td>
<td>Inquiry learning, cooperative learning</td>
<td>1.11</td>
</tr>
<tr>
<td>2000a, b</td>
<td>Palmer</td>
<td>Cooperative learning, student-centred investigation</td>
<td>0.92</td>
</tr>
<tr>
<td>2011</td>
<td>Bautista</td>
<td>Integration with other KLA, inquiry learning, in-subject practical experience, link to professional experience blocks, nature of science focus, alternative conception targeting</td>
<td>0.85</td>
</tr>
<tr>
<td>2010</td>
<td>Cross</td>
<td>Constructivism, mentoring, curriculum development, inquiry learning, in-subject practical experience, cooperative learning, student-centred investigation, alternative conception targeting</td>
<td>0.81</td>
</tr>
<tr>
<td>2009</td>
<td>Bleicher</td>
<td>Constructivism, curriculum development, cooperative learning</td>
<td>0.75</td>
</tr>
<tr>
<td>1999</td>
<td>Wingfield and Ramsey</td>
<td>Mentoring, curriculum development, in-subject practical experience, cooperative learning</td>
<td>0.71</td>
</tr>
<tr>
<td>2013</td>
<td>Deehan</td>
<td>Constructivism, problem-based learning, Integration with other KLA, curriculum development, inquiry learning, in-subject practical experience, cooperative learning, ICT instruction, student-centred investigation, Rich Tasks</td>
<td>0.70</td>
</tr>
<tr>
<td>2015</td>
<td>Knaggs and Sonderegeld</td>
<td>Curriculum development, inquiry learning, in-subject practical experience, student-centred investigation, nature of science instruction</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Elementary science curriculum (Deehan 2013). Both subjects produced STOE effect sizes that were significantly higher than the literature mean and were durable for up to 12-months after the end of the second subject. Also, it should be noted that this cohort of pre-service teachers displayed equivalent mean scores on both the PSTE and the STOE subscale on the final STEBI-B administration. Such subscale equality is unprecedented within the STEBI-B literature and represents an ideal goal in the science teaching efficacy of pre-service elementary teachers. However, given the lack of research linking pre-service to in-service teaching, it remains unclear how such efficacious gains influence the science teaching practices of in-service teachers. The following section will discuss the implications and research directions that should arise from the STEBI-B analyses conducted within this chapter.


**Discussion**

Throughout its 25 year existence, the STEBI-B has been employed in a variety of compelling and worthwhile research projects. The instrument has been used as: a basis for deep qualitative interviews (e.g. Tosun 2000); a means of assessing science teaching efficacy beliefs with other variables (e.g. Serin and Bayrakter 2014); a way of assessing science education subjects (e.g. Swars and Dooley 2010); and even as: a way of assessing the cumulative effects of entire teacher education programs (e.g. Gins et al. 1995). The reliability and validity of the STEBI-B instrument has lead to its use as a basis for the development of alternate efficacy instruments (e.g. Wilson 2012). The body of literature appears to show a shift from identifying science teaching efficacy issues to rectifying such issues. This is evident as there has been a trend towards rigorous research designs with multiple administrations of the STEBI-B instrument. In fact, multiple administrations of the STEBI-B instrument were used to obtain relevant statistical data in 60% of the analysed articles. Yet, pathways remain for the improvement of the methodological implementation of the STEBI-B instrument within the body of literature. The overwhelming absence of experimental designs in the literature prevents the establishment of causal relationships between science interventions and STBIs. Although, many researchers have attempted to strengthen the argument for covariance by reporting on multiple cohorts (e.g. Cone 2009; Ford et al. 2011), there are still only 8 research items that have employed the STEBI-B in an experimental framework. The widespread lack of causal relationships within the STEBI-B literature may, at least in some part, be connected to the large variation in the pedagogical practices employed within tertiary science interventions (e.g. Palmer 2007).

The STOE subscale is problematic in comparison with the PSTE subscale. The body of literature reveals that the STOE is almost always lower than the PSTE on all administrations of the STEBI-B. In fact, of the 83 articles that measured both the PSTE and STOE subscales on at least one occasion, the mean STOE score was higher than the mean PSTE score only five times (e.g. Bursal 2011; Cross 2010; Deehan 2013). There is a similar disparity in the effect size changes reported on the STOE-B subscales. The mean effect size change on the PSTE scale (0.83) is nearly twice as large as that on the STOE scale (0.43). In summation, pre-service primary teachers generally feel more efficacious about their capacity to teach science effectively then they feel about the ability of science teachers in general to guide students towards desired learning outcomes.

Criticisms of both the validity and reliability of the STOE subscale have been presented as reasons for its removal from research designs (Andersen et al. 2004; Bursal 2008; Cannon and Scharmann 1996; McDonough and Matkins 2010; Velthuis et al. 2014). Bursal (2010) diminished the validity of the construct by claiming that the statements comprising the STOE subscale align with a 'teacher-centred' approach to science teaching that does not reflect modern educational principles. An analysis of the STOE items refutes this interpretation. Indeed, the statements comprising the STOE subscale appear to be pedagogically neutral.
Other researchers cite the low reliability of the STOE measure as a reason for dismissal (Andersen et al. 2004; Velthuis et al. 2014). Velthuis and others (2014) found that the STOE subscale produced a Cronbach’s alpha of 0.56 in a Danish university and subsequently removed it from the research. Such findings are common within the literature as the reliability of the STOE subscale is generally lower than the PSTE subscale (Aydin and Boz 2010; Bleicher 2004; Cross 2010; Deehan 2013; Enoch and Riggs 1990). Cannon and Scharmann (1996) appear to be resigned to low reliability on the STOE subscale, as they believe that pre-service teachers lack the necessary conceptualisations of the teaching profession to respond to the STOE statements appropriately. It could be argued that it is the purpose of pre-service teacher training to provide students with the opportunities to develop such conceptual understandings of the profession. Longitudinal research reveals that the reliability of the STOE subscale improves as pre-service teachers progress through their degrees, even in the absence of formal science education (Cross 2010; Deehan 2013).

There is considerable pedagogical variation amongst the science interventions presented in the STEBI-B literature. Curriculum development, inquiry learning, and in-subject practical experiences are the most common pedagogical inclusions within the STEBI-B literature. ICT instruction, links to professional experiences placements and problem-based learning were all conspicuously absent from the body of research. Educational designs with multiple innovative practices and deep collaboration beyond the immediate subject tend to covary with higher effect sizes on the PSTE and STOE subscales. Student centred approaches and practical science teaching experiences were used within the science interventions that produced the strongest growth in personal science teaching efficacy. Conversely, analyses revealed that there is no simple pedagogical solution to producing high effect size gains on the STOE subscale. This can likely be attributed to the varied, external locus of control of the broader science teaching outcome expectancy subscale. The number of innovations used within science interventions appears to be a stronger predictor of STOE growth rather than the types of innovations used. Yet, the simplification of content also covaries with improved STOE scores (Ozdelik and Bulunuz 2009; Palmer 2006a, b). Such dissonance between content and pedagogies in the research trends resembles the broader issues that are frequently mentioned in relation to the STOE subscale.

While many researchers are reporting positive correlations between science interventions and the STEBs of participants, the durability of any positive changes remain unknown. Only 8.5 % of the analysed research items assessed the durability of the participants’ STEB changes in the absence of a formal science treatment. If the purpose of the tertiary science education programs is to prepare future teachers to deliver quality science education, then logic dictates that the durability of intervention outcomes must be considered both within and beyond the tertiary context. Currently there are few articles that extend the STEBI-B literature into the in-service teaching domain (e.g. McKinnon and Lamberts 2013). Given the changing demographics of the elementary teaching workforce, as the ‘baby boomer’ generation nears retirement (Harris and Farrell 2007; NSW DEC 2011),
it is imperative that the transition from pre-service to in-service teaching becomes a major research focus in the future.

The framework developed for the organisation of the STEBI-B literature serves the primary function of organising a large body of literature into a coherent format whilst still allowing for broader trends to be analysed. The methodological funnel allows the reader to consider the different methodological and content contributions made to the science teaching efficacy field. Each level of the funnel establishes knowledge that is built upon in the levels that follow. The framework has allowed for innovative practices to be identified and for science teaching efficacy belief effect sizes to be compared across different contexts. Nevertheless, we are still confronted by the “question mark” showing that a relationship exists between reported innovative practices and science teaching efficacy effect size. As an outsider, the researcher cannot know what complex interactions occurred across each classroom within each university to lead to the reported changes. Even still, we cannot yet know what these “changes” mean in a tangible fashion. This provides an argument for the mixed methods approach to science education research. It should be noted, that while not an explicit focus of this review paper, many researchers recognised these issues and employed mixed methods designs (e.g. Bleicher and Lindgren 2005; Leonard et al. 2011; Scott 2013).

The findings presented within this STEBI-B review have considerable implications for the direction of further research. Firstly, the STEBI-B needs to be adopted in contexts beyond Australia, Turkey and the USA. Specifically, more research into the reliability of the STEBI-B subscales needs to be conducted beyond the USA. Currently, there is a tendency to restate the reliabilities reported by the seminal authors (Enochs and Riggs 1990) and other major updates (Bleicher 2004). Secondly, the STEBI-B should be used with a greater number of longitudinal and experimental research designs. The use of these more complex research designs would serve the dual purposes of allowing for causal links between tertiary science interventions and reported STEB changes. Longitudinal follow-ups can assess the durability of efficacious gains beyond tertiary contexts. Presently, the STEBI-B literature exemplifies the disconnection between research into the pre-service and in-service domains of elementary science education. More research needs to employ the STEBI-B and STEBI-A instruments to traverse the gap between pre-service and in-service teaching to determine if STEBs remain durable after teachers leave the tertiary context. Thirdly, more researchers should consider presenting the narrative of subject development over time. Given that the most successful science interventions feature complex pedagogical structures, overviews as to how these interventions were developed would serve as meaningful models for replication. Finally, the TOE subscales need to be considered in both the development of science interventions and the presentation of research. This review has shown that the outcome expectancies of pre-service teachers can be improved with pedagogically complex, student-centred science interventions. While the arguments for the dismissal of the TOE subscale are compelling, addressing these issues would advance the body of research into valuable new directions.
References


Legerwell, M. G. (2009). *The effects of a summer science camp teaching experience on preservice elementary teachers’ science teaching efficacy, science content knowledge, and understanding of the nature of science* (Doctoral dissertation, George Mason University).


Chapter 3
A Review of the Science Teaching Efficacy Belief Instrument A: In-service Teachers

Abstract At a time where scientifically literate citizens are needed to make informed decisions about global issues, the importance of science education cannot be overstated. Due to the wide array of stakeholders, perspectives and goals it can be challenging to find consistent trends across the literature. The Science Teaching Efficacy Belief Instrument A (STEBI-A) has proven to be a valid and reliable measure of teachers’ science teaching efficacy beliefs for over 25 years. The purpose of this chapter is to consolidate the body of STEBI-A literature through a structured review of the methods and findings in this area of science education research. A total of 107 articles and dissertations were deemed to have used the STEBI-A instrument and were subsequently included in the analyses. The findings showed that the instrument has been employed in varied research designs across 15 different national contexts to provide valuable insights into the nature, growth and cross-variable relationships of teachers’ science teaching efficacy beliefs. Analysis of interventions that were assessed via the STEBI-A showed professionally relevant, resource rich science programs could enhance the personal science teaching efficacy beliefs of in-service teachers across a multitude of contexts. Teachers often expressed cynical views as their personal science teaching efficacy scores were higher than their general science teaching outcome expectancies. Improving teachers’ science teaching outcome expectancies should be an aim for future research. More implications are discussed within the chapter.

The Science Teaching Efficacy Belief Instrument—A

The Science Teaching Efficacy Belief Instrument A (STEBI-A) was developed to measure the personal and general aspects that comprise an in-service teacher’s science teaching efficacy beliefs (Riggs and Enochs 1990). The constructs that comprise the two subscales of the instrument are Personal Science Teaching Efficacy beliefs (PSTE) and Science Teaching Outcome Expectancies (STOE). The PSTE subscale measures respondents’ beliefs about their own capacity to deliver science teaching experiences that assist students to develop predetermined science skills.
and knowledge. An example of an item on the PSTE subscale is “I find it difficult to explain to students why experiments work”. The STOE subscale measures respondents’ beliefs about the capacity of science teaching to overcome external factors to aid students’ science learning in a general sense. An example of an item on the STOE subscale is “Students’ achievement in science is directly related to their teacher’s effectiveness in science teaching”. The original STEBI-A is a 30-item Likert questionnaire wherein respondents rate their level of agreement with set statements on a 5-point scale ranging from ‘strongly agree’ to ‘strongly disagree’. Over the course of its 25-year existence the STEBI-A instrument has been used to make meaningful contributions to a broad array of different research contexts.

The Research Contexts of the STEBI-A Instrument

The researcher acknowledges that technological limitations may mean that the research collected within this review may not be an exhaustive representation of the STEBI-A usage. Despite claims relating to the outdated nature of the science teaching efficacy beliefs instruments (Mulholland et al. 2004), use of the STEBI-A instrument has been rising dramatically. The STEBI-A instrument was adopted at a modest rate during its first decade of research use (1990–1999), with an average of 1 research item utilising the instrument per year. During the following decade (2000–2009), the use of the STEBI-A more than quadrupled to a rate of 4.4 research items per year. Over the past four years (2010–2014), the uptake of the STEBI-A has risen significantly to 12.75 research items per year. In fact, the number of research items employing the STEBI-A in the past 4 years (51) has already exceeded the entire output of the previous decade (44).

The overwhelming majority of the STEBI-A literature is situated within the American context. However, in recent years other nations have begun contributing to the existing body of STEBI-A literature. Figure 3.1 outlines the STEBI-A research output by nation. The United States accounts for 72% of the STEBI-A research, with a total over seven times higher than the next most productive nation, Australia. In a similar trend to the STEBI-B instrument, the STEBI-A instrument has been used consistently within Turkish contexts over the past decade. A promising finding was the emerging trend of STEBI-A usage within differing cultural, economic and educational contexts. The STEBI-A instrument has been introduced to following national contexts: China (Sang et al. 2012), Denmark (Andersen et al. 2004), Ecuador (Lucero et al. 2013), India (Desouza et al. 2004), Iran (Fathi-Azar 2002), Israel (Eshach 2003), Netherlands (Velthuis 2014), Taiwan (Liu et al. 2008) and the United Arab Emirates (McKinnon et al. 2014). Such widespread use of the STEBI-A instrument may be related to global recognition of the importance of science education. There may also be opportunities in the future for comparative STEBI-A research across multiple contexts (e.g. Batiza et al. 2013). This will be unpacked further in the discussion section.
Fig. 3.1 Summary of the STEBI-A use of different nations

**Purpose of This Chapter**

There are three aims for this chapter. The first aim is to organise and describe the research employing the STEBI-A instrument from a methodological perspective. The second aim is to provide an overview of how the STEBI-A subscales have been used within the literature. The final aim is to explore and rank the innovative practices used within science interventions through the use of STEBI-A effect sizes as a comparison point. All of these aims will be achieved within the organisation framework presented in the previous STEBI-B review chapter.

**Method**

This chapter reports on a review of multiple research items that utilise the STEBI-A instrument. Such an approach allows for a clear understanding of how the research in science education has developed over the past 25 years. A variety of literature search techniques were used to acquire research items that have employed the STEBI-A instrument since its development in 1990. The acquired research items were coded for comparison in the following areas: context, research design, intervention, delivery, participants, use of subscales (PSTE and STOE) and effect sizes (Cohen’s D). The following subsections will describe both the literature search procedures and the subsequent coding and analytic procedures used with relevant research items.
Inclusion Criteria

A broad inclusion criterion (Suter 2006) was used for the literature search. This allows for research beyond the author’s conceptualisations to be considered. The criterion was:

- The STEBI-A instrument is used to inform the research in a meaningful way. This accounts for the diverse contexts within which the STEBI-A can be employed.

Literature Collection Procedures

The initial search for literature occurred in 4 phases:

1. **Seminal author search**—The article discussing the development of the STEBI-A instrument by the seminal authors (Kervin et al. 2006) was found using “Google Scholar”.

   Riggs and Enochs (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. Science Education, 74(6), 625–637. Articles that referenced the seminal STEBI-A authors were tracked through a backward mapping approach (Green et al. 2006). The method yielded 116 relevant articles.

2. **ERIC Search**—The Education Resource Information Centre database was specifically searched with the use of the terms ‘STEBI-A’ and ‘Science Teaching Efficacy Belief Instrument A’. An additional 5 articles were found that appeared to fulfill the inclusion criteria for the review.

3. **Primo Search**—The Charles Sturt University Primo search website was used to search for relevant literature. Primo affords access to an assortment of journals, newspaper articles, books, Ebooks and CSU research output. ‘STEBI-A’ and ‘Science Teaching Efficacy Belief Instrument A’ were utilised for this search. The Primo Search uncovered 9 research items that appeared relevant to the review.

4. **EBSCO Host Search**—The EBSCO Host search allowed the research to gain access to over 200 education based academic journals. The key search terms of ‘STEBI-A’ and ‘Science Teaching Efficacy Belief Instrument A’ returned 2 relevant articles that incorporated the STEBI-A instrument.

5. **Minor Journal Searches**—An array of minor research data bases were searched via the key terms of ‘STEBI-A’ and ‘Science Teaching Efficacy Belief Instrument A’. The minor data bases included; Cambridge Journals, CBCA Database, Emenau, Expanded Academic ASAP, Infotrac, Factiva, Informit, Web of Knowledge, JSTOR, Oxford Journals, ProQuest, SAGE Journals Online, ScienceDirect (Elsevier SD), Scopus, Springerlink, Taylor and Francis Online, and Wiley Online Library. Ten additional relevant items were found amongst these journals.

A total of 142 relevant research items were collected during the literature collection phase. When repeated and inappropriate articles were removed, the number of articles included in the analysis was reduced to 124. An additional 17 articles were removed as the STEBI-A had been incorrectly administered to
Coding and Analysis

The following subsections outline the coding and analysis procedures used for the STEBI-A papers. Coding and analytic procedures will be outlined for research approaches, interventions, and the use of effect sizes.

Research Approaches

The research items were coded based on the methodologies within which the STEBI-A was employed. Qualitative use of the STEBI-A was coded as a zero, due to the difficulty in relating findings to alternate contexts. Quantitative or mixed methods research designs were coded based on the number of STEBI-A administrations. It should be noted that the codes do not represent judgements on the quality of the different research designs. Table 3.1 describes the research approaches and codes for the targeted research items.

To supplement the research design analyses, the research items were coded in additional ways. Firstly, the subscale differentiation (PSTE and STOE) was coded on a 3-point scale. A score of zero indicated that the subscale was not present, a score of 1 indicated that the subscale was merged, and a score of 2 indicated that the subscale was present. Secondly, the descriptive statistics of the qualifying studies were coded in terms of overall quality, within an underlying focus on the calculation of Cohen’s D effect sizes for intra-study comparisons. A score of zero indicated that the descriptive statistics could not be found, a score of 1 indicated that the descriptive statistics were present but incomplete and a score of 2 indicated that the descriptive statistics were complete.

Intervention Coding

The articles that reported on a science intervention were coded based on the pedagogical innovations included in the educational design. A framework was initially developed from Lawrence and Palmer’s (2003) description of innovative practices within tertiary science programs. The framework was modified to suit the in-service teaching context via a thorough manual analysis of the STEBI-A literature. Many of these innovations have overlapping elements but enough differentiation exists in the literature for separate definitions. The framework provides a useful, but not infallible, list of innovative practices. Other researchers should continue to make additions to and refine this list. Table 3.2 explains the selected innovative practices. A total of 15 approaches comprise this ‘innovative practices’ framework. The researcher acknowledges that this is not an exhaustive list of potential pedagogical approaches.
<table>
<thead>
<tr>
<th>Code</th>
<th>Research type</th>
<th>Number of STEBI-A uses</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Experimental design</td>
<td>&gt;2</td>
<td>Experimental designs allow for cause and effect statements to be made rather than correlational observations. This research design is comprised of two groups. The experimental group is exposed to a formal treatment. A control does not receive the treatment. Where possible extraneous variables are controlled through randomised group assignment. However, in educational research it is often ethically impossible to randomly assign participants to either group.</td>
</tr>
<tr>
<td>3</td>
<td>Longitudinal quasi experimental pre/post design</td>
<td>&gt;2</td>
<td>Research where a pre- and post-test STEBI-A implementation is supplemented by delayed testing to determine the longevity of any efficacious changes in the absence of formal science treatment</td>
</tr>
<tr>
<td>2.5</td>
<td>Quasi experimental pre/post—with multiple cohorts</td>
<td>&gt;2</td>
<td>Research where multiple cohorts of participants respond to pre- and post-test versions of the STEBI-A, as they undertake a specified intervention</td>
</tr>
<tr>
<td>2</td>
<td>Quasi experimental pre/post</td>
<td>2</td>
<td>Research where a cohort of participants provide STEBI-A data, both before and after, undertaking a specified intervention</td>
</tr>
<tr>
<td>1.5</td>
<td>Equivalent groups</td>
<td>2</td>
<td>Research where pre and post intervention STEBI-A data are collected from separate groups and compared as equivalent data (Suter 2006)</td>
</tr>
<tr>
<td>1</td>
<td>Cross sectional</td>
<td>1</td>
<td>Research where the STEBI-A was administered to a single group on one occasion to make comparisons with other variables</td>
</tr>
<tr>
<td>0</td>
<td>Qualitative/alternate research approaches</td>
<td>Variable</td>
<td>There are two primary types of research that fall into this category. Firstly, research where the STEBI-A instrument was not used to provide statistical data, as originally intended by the seminal authors, i.e., qualitative research (Riggs and Enochs 1990). Secondly, research where the STEBI-A instrument was outlined in the methodology, but the subsequent STEBI-A data was not presented.</td>
</tr>
<tr>
<td>Innovative practice</td>
<td>Description</td>
<td></td>
<td></td>
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<tr>
<td>-------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructivism</td>
<td>Learning that occurs when an individual constructs their knowledge through active participation (i.e., discussion) within a phenomenon or situation (Slavin 1991; Vygotsky 1977)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem-based learning</td>
<td>Problem-based learning is a deep learning strategy that helps students to develop transferrable skills, which can be used in novel situations (Schmidt et al. 2006). Problem-based learning uses real-world problems as a starting point for the acquisition and integration of new knowledge into existing schemas (Azer 2001; Kahn and O’Rourke 2005)</td>
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</tr>
<tr>
<td>Integration with other Key Learning Areas (KLAs)</td>
<td>An approach to teaching where two disciplines, that are considered fundamentally separate, are integrated to create deep learning outcomes. For example, allowing students to collect and graph data is an example of a deep integration between mathematics and science. For the purposes of this analysis, this ‘innovative practice’ was split into two sub-categories: ‘Deep links to mathematics (STEM)’ and ‘Integration with other KLAs’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentoring</td>
<td>Mentoring is an emerging practice where teachers are paired with more experienced expert teachers or outside experts in order to focus on a particular discipline. The teachers observe the experienced teachers and receive feedback on their own teaching practice</td>
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<td></td>
</tr>
<tr>
<td>Curriculum development/real world relevance</td>
<td>This term broadly encompasses teaching pedagogies and learning opportunities that accurately reflect the responsibilities and actions of the teaching profession. Within the context of this review paper this would include approaches such as allowing teachers to develop units of work and other resources that can be used in their own teaching practice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inquiry learning</td>
<td>Inquiry learning allows participants to develop transferrable skills and knowledge to seek the information needed in order to achieve a task (Duran et al. 2009; Edelson et al. 1999). Open inquiry occurs when the participants have complete control over inquiry processes. Guided inquiry occurs when some instruction and support is provided</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School partnership</td>
<td>This occurs when the intervention is designed with imbedded opportunities to teach science to students of the intended year levels. The research item may describe an ongoing relationship between the group providing the science intervention and school groups</td>
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<td></td>
</tr>
<tr>
<td>Tertiary partnership</td>
<td>This occurs when there is an explicitly stated relationship between the intervention providers and a pre-service teaching institution. Such a relationship allows for tertiary benefits (science subjects, on-campus resources, and access to relevant experts) to be received by participating in-service teachers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperative learning</td>
<td>Cooperative learning occurs when teachers work together in separate, complimentary roles to complete a task that would otherwise be impossible to complete individually</td>
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<td></td>
</tr>
<tr>
<td>ICT instruction/incorporation</td>
<td>The teachers explicitly learn about the use of ICT in a way that is relevant to classroom teaching practice. For example, the use of Interactive Whiteboard Software for creating learning aids</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continued)
Table 3.2 (continued)

<table>
<thead>
<tr>
<th>Innovative practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student-centred investigation</td>
<td>These are investigations where the teachers assume the locus of control within the confines of the subject. Ideally, teachers should have control over all stages of the investigation, with the instructor acting in a facilitative role.</td>
</tr>
<tr>
<td>Authentic tasks/real world experiences</td>
<td>Authentic tasks are those that are clearly related to the profession/career that the students are studying to enter. Examples may include developing units of work, practical experiences, researching student misconceptions. Real world experiences refer to learning experiences where the participant engages in scientific practices which either model true scientific practice and/or present science with real world applications.</td>
</tr>
<tr>
<td>Nature of science</td>
<td>The understanding that scientific knowledge is fluid and always subject to reasonable debate. Instruction in this area may orient the learner to the variety of scientific approaches beyond an experimental research design.</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>A misconceptions based approach is a practice where the misconceptions of the students/teachers are identified and revealed to them. Such misconceptions inform the development of personalised curricula. This approach can be used to aid a teacher science intervention whilst serving as a model for in-class science teaching practice.</td>
</tr>
</tbody>
</table>

The interventions were coded dichotomously as either including (1) or not including (0) each innovative practice. The judgement was based upon the author's thorough reading of the intervention descriptions, which were supplemented by the use of a search function to assess the inclusion of key terms. An innovative practice did not have to be explicitly explained within an intervention to be classified as 'included', rather the practice had to be evident within the description based on the informed reading of the researcher. The quality and depth of innovative practices were not differentiated in this coding scheme. The author acknowledges that the coding of each intervention may not be complete as practitioners may have been missed or misinterpreted. The interventions were also coded for both the delivery and length of the programs. The delivery was coded at 3 levels: online (1), face-to-face (2) and mixed (3). The program lengths were coded as: single workshop (2), multiple workshops (2), and multiple workshops with in-school support (3).

Using Effect Sizes to Evaluate the Interventions

STEBI-A research that administered the instrument to the participants at least twice (coded ≥ 1.5 for research design) over the course of a specified intervention were analysed for Cohen's D effect sizes. This allowed the research to determine which interventions, and the corresponding pedagogical approaches, correlated with the largest effect size increases for the PSTE and STOE scores of participating in-service teachers. For research that reported on two or more cohorts, a
mean effect size was calculated. Secondly, when an outlier (> or <0.5 above other cohorts) was present in research reporting on 3 or more cohorts, the median score of all cohorts was used to represent the research.

**Structural Framework for the Analysis of the STEBI-A Literature**

The structural framework was introduced in the first chapter as a means to succinctly describe and analyse research employing the Science Teaching Efficacy Belief Instrument B (STEBI-B) (Enochs and Riggs 1990). As the STEBI-B and STEBI-A instruments measure the same constructs with minor contextual modifications, the structural framework can be applied to both instruments. Figure 3.2 shows the framework for the STEBI-A analysis. The blue sections show the research designs and the red sections show the innovations/effect size analyses. The research designs outlined in the inverted blue triangle are arranged in approximate order of the number of STEBI-A uses. The red triangle represents evaluative research designs that assessed a science intervention with at least two administrations of the STEBI-A instrument. The red arrows show the information that was extracted from these evaluative research articles. The left circle of the Venn diagram shows

![Fig. 3.2 STEBI-A structural review framework](image-url)
the innovative practices reported in the relevant literature. The right circle shows the STEBI-A effect sizes reported within the analysed literature. It should be noted that the effect sizes are moderated by researchers’ usage of the PSTE and STOE subscales. The intersection of the Venn diagram acknowledges and represents the unknowable relationship between the interventions and the report effect sizes.

Findings

The findings will be presented as separate research design and innovative practices sections. Firstly, the STEBI-A research design section will provide a holistic overview of how the instrument has been employed within the literature. Secondly, the focus will tighten to focus on research that describes science interventions and/or evaluates those interventions with STEB effect sizes.

STEBI-A Research Designs

The following subsections will describe the different research designs that have used the STEBI-A instrument. The research designs have been evaluated based on the both the use of the STEBI-A instrument and the number of administrations. A funnel has been created as articles and dissertations are removed at the end of each section. All 107 STEBI-A research projects were considered in this analysis.

Qualitative Research and Alternate STEBI-A Uses (0)

Many researchers have chosen to use the STEBI-A in qualitative research designs. A steady flow of qualitative research has been published with the intent to bridge the gap between teachers’ pre-service and in-service science teaching efficacy beliefs. Ginns and Watters (1996) followed the early career experiences of two case study participants. The results showed that the school environment (experienced teachers and administrators) played a crucial role in developing the science teaching efficacy beliefs of novice teachers. Saka (2007) also found that the professional school contexts played an important role in shaping the science teaching practices and efficacy of two early career teachers. Contradictions between university and professional school contexts appear to place considerable stress on early career teachers. In fact, one participant in Saka’s (2007) research changed his personal goal for science reform due to such contradictions. Ginns and Watters (1999) used the STEBI-A to frame interview and video data collected from four case study teachers. It was found that the four novice teachers all drew heavily from their tertiary experiences to develop constructivist, student centred science
Qualitative STEBI-A research often serves to illuminate issues that arise during the transition from pre-service to in-service status. Yet, deeper quantitative and mixed method research is needed to complement these inductive trends. Larger sample sizes are needed to ensure the generalisability of findings in the future.

Researcher choices in terms of STEBI-A usage and reporting have lead to a number of research items being classified as alternate. While this does limit the relevance of these studies in the context of this review, it does not diminish wider contributions. Some researchers chose not to report STEBI-A results despite identifying the instrument as a tool for data collection (Duran et al. 2010; Shroyer et al. 1996). The choice to omit STEBI-A data is not always problematic. For example, Urquhart and Bober (2006) produced a paper with the primary aim of describing a Physics-based professional development course rather than evaluating it. The STEBI-A was described as an evaluative tool within the course design.

In another circumstance, the STEBI-A was modified to an extent that greatly reduced the capacity of the research to be compared with other STEBI-A research. Specifically, Taylor (2005) created a combined Environmental and General Science Teacher Efficacy instrument by combining items from the STEBI-A with other instruments. Ultimately, researchers’ data collection and reporting choices will always be informed by factors of context and publication requirements. While such choices may appear to limit the research in the context of this review, it does not diminish the overarching contribution of these papers to the literature base.

Science interventions and other forms of professional development are the subjects of some papers coded at the qualitative/alternate level. Watters and Ginns (1997) explored how a single teacher responded to a ‘Simply Science’ program where 25-minute science television programs were broadcast to students and supplemented by follow-up science lessons. While the experienced teacher showed no change in her science teaching efficacy beliefs, she did show improved Pedagogical Content Knowledge (PCK) and better attitudes to constructivist teaching approaches. The importance of PCK has been reaffirmed in later research. Nafziger (2008) found that the self-efficacy of three teachers participating in a standards-based, inquiry science program only improved if their developing science content knowledge could be connected directly to their teaching practice. Saka et al. (2009) found that science teaching efficacy was not a key blocking factor in 3 teachers’ enactment of inquiry teaching practice. Instead pedagogical discontentment, perceptions of students’ ability levels and external contextual pressures were identified as key factors that needed to be addressed to ensure the enactment of inquiry teaching. Ogobono (2010) reported on a museum-based, science professional development program that made clear contextual links for teachers in terms of resources and curricular relevance. These linkages appeared to produce positive results as the six teachers reported improve science teaching efficacy and science content knowledge. The main point of contention was the absence of in-school follow-up research. The average number of participants in science intervention research at this level is nine. This means that the findings cannot be generalized to form more definitive conclusions. Nevertheless, the rich findings of the research at this level have informed and will continue to inform the
direction of future research. A total of 14 pieces of research used the STEBI-A instrument in either qualitative or alternate research designs. The remaining 93 studies were considered in the next step of the research designs analysis.

Cross Sectional Research Designs (1)

Much of the cross sectional STEBI-A research explores the relationship between science teaching efficacy and classroom practices. Burton (1996) found that statistically significant positive correlations existed between the science teaching efficacy beliefs and reported constructivist science teaching practices of a sample of 285 American elementary teachers. Lardy (2011) found a similar positive correlation between science teaching efficacy and reported constructivist teaching beliefs. Classroom observations showed that these beliefs were not evident in science teaching practice. Secondary school science teachers may have similar preferences for transmissive, teacher centred approaches. In a sample of 86 secondary science teachers, those with high and low science teaching efficacy beliefs displayed similar preferences for traditional methods of instruction (Hodgin 2014). Lucero et al. (2013) suggest that teachers with higher personal science teaching efficacy may be more likely to give students autonomy in their inquiry learning. Highly structured and supported professional development opportunities can improve teachers’ science teaching efficacy and the frequency of their science teaching practice. Albion and Spence (2013) found that teachers’ who used Primary Connections curriculum materials reported both higher science teaching efficacy scores and high science teaching frequency than teachers’ who did not have access to the same materials and support.

Cross sectional STEBI-A research has been used to assess the relationships between science teachers and other stakeholders. In recognition of the core goals of both elementary and secondary science education, some STEBI-A research connects teacher science efficacy with student characteristics and learning outcomes. A survey of 225 teachers showed that there was no significant relationship between teachers’ STOE scores and their students’ economic level or ethnicity. Curiously, teachers who classified their students as coming from a middle/upper income background had higher PSTE scores than their counterparts who classified their students as coming from low income backgrounds. Science teaching efficacy may be partially related to student outcomes. Angle and Moseley (2009) assessed the science teaching efficacy beliefs of secondary biology teachers whose students’ outcomes both fell below the proficient level and reached the proficient level. The teachers with students performing at proficient levels reported higher STOE scores. There was no difference in PSTE based on student achievement level. Other research suggests school leadership is related to teachers’ PSTE scores. Clark (2009) found that teachers with higher PSTE scores described their principals as engaging in positive leadership practices such as: staff goal
discussion, science curriculum reviews, recognition of student progress and the encouragement of innovative teaching approaches.

Education variables such as content knowledge and tertiary experiences have underpinned some of the cross sectional STEBI-A research. Desouza et al. (2004) administered the STEBI-A instrument and a demographic survey to over 300 Indian middle school teachers. There was a strong positive correlation between teachers’ level of education and their STEB scores. A curious finding was that the correlation between the PSTE and STOE subscales weakened as the level of teacher education attainment increased. In fact, there was no significant correlation between PSTE and STOE for the teachers with Bachelors’ Degrees but no preparatory practical science teaching experience. Lekhu (2013) found that there was no relationship between the science qualifications and science teaching efficacy beliefs for 99 South African secondary science teachers. It was noted that higher STOE scores were associated with higher professional teaching qualifications. In a sample of 113 primary teachers, Saint (2013) conducted regression analyses to find that pre-service science education experiences account for 34% of the variance in teachers’ science teaching efficacy belief scores. In-service professional development accounted for 39% of the variance in STEBI-A scores. Both pre-service and in-service training showed significant predictive relationships with science teaching efficacy beliefs. After the 38 cross sectional studies were eliminated, the pool of research papers decreased to 55.

Research with Equivalent Groups (1.5)

None of the analysed articles employed an equivalent groups design.

Quasi Experimental Designs with a Single Cohort (2)

A large proportion of the quasi experimental STEBI-A research evaluates the effectiveness of professional development programs. Professional development practices such as: peer teaching (Fison et al. 1992); field trip experiences (Kean and Enoch 2001); practical teaching experiences (Naizer et al. 2003); the SEs framework (Shea et al. 2013) and problem-based learning (Ertmer et al. 2014) have all been evaluated through pre- and post-test administrations of the STEBI-A instrument. To avoid redundancy this section will discuss the quasi-experimental, single cohort research with smaller numbers of participants. Holbert et al. (2011) aimed to foster relationships between schools and universities by offering research experiences for 14 experienced teachers. After completing the program the participants reported increased interest in science and mathematics research. There was evidence of a rift between schools and universities as the respondents displayed no science teaching efficacy growth and were critical of
the performance of their university instructors. Thomas et al. (2013) described a Geology content program delivered by tertiary experts. The seven participants showed large effect size increases in their PSTE scores, but their STOE growth was negligible. Rather than addressing science content knowledge deficits, Pinell et al. (2013) described a STEM education framework that engaged 10 in-service teachers in curriculum development and research experiences. The STEBI-A results were the inverse of those reported by Thomas et al. (2013) as the STOE showed significant change whilst the PSTE remained stagnant. The sample size of 6 teachers on the post-test is severely limiting in this research as statistical assumptions cannot be met.

The research at this level shows an emerging trend of long-term professional development delivery with increased opportunities for participants to connect with instructors. Haney et al. (2007) reported on the teacher outcomes from participation in a 2-year professional development program wherein participants developed integrated science programs in a problem-based learning environment. The results aligned with broader literature trends as the 18 participants displayed increased PSTE scores, improved attitudes towards non-traditional science teaching practices and small, but significant, declines in their STOE scores. Kuchey et al. (2009) describe a similarly structured 2-year professional development program where the 18 teachers participated in monthly workshops. The program was content driven, used constructivist approaches and integrated mathematics with science. The teachers displayed strong increases in their science teaching efficacy beliefs, but the merging of the subscales prevents meaningful comparisons to other STEBI-A research. The long-term delivery of the professional development allowed the schools to complete site based science and mathematics improvement programs to extend beyond the duration of the program itself. Other programs have been supplemented with online learning opportunities to foster comparably deep links for teacher participants. Gosselin et al. (2010) described and evaluated the online ‘Laboratory Earth’ program. The 51 participating teachers had access to online modules, support materials, instructor support and discussion forums to allow for effective synchronous and asynchronous learning. The results showed both science teaching efficacy and content knowledge increases for the participating teachers. Other programs have included online components to supplement science professional development programs. Online meeting sessions have been used to facilitate curriculum development opportunities for practicing teachers (Holbert et al. 2011). Online assessment and feedback have also been used to recognise the prior knowledge of in-service teachers (Rudman and Webb 2009). It appears as though the STEBI-A research is only just beginning to explore the potential of long-term professional development models supplemented by online delivery. There were 22 studies that used the STEBI-A instrument to record pre- and post-test data from a single cohort of participants. There were 33 research pieces that were carried over to the next level of analysis.
Quasi Experimental Designs with Multiple Cohorts (2.5)

Research where STEBI-A data has been collected from multiple cohorts affords excellent opportunities for “between group” comparisons. Some research reveals consistent STEB growth in participants across numerous iterations of science programs. Roberts et al. (2001) found that an inquiry-based science professional development program produced large PSTE effect size changes for the 330 teachers who participated between 1992 through to 1999. Of note was that there were no statistically significant differences between the year groups despite changes to the length of the program. Shin et al. (2010) described remarkably uniform small-to-moderate science teaching efficacy gains in the 75 teachers who participated in a problem-based learning professional development program. In fact, across the four years of data collection (2006–2009) antecedent variables such as teaching experience and previous professional development had no significant impact on participants’ science teaching efficacy scores. In other cases, research at this level (2.5) highlights inconsistencies in the STEB results across different iterations of science professional development programs. For example, two cohorts involved in a teacher centred systemic reform model showed considerable disparities in their PSTE effect sizes, with the first group showing no change but the second group showing large effect size growth (Saka et al. 2009). Similar inconsistency between group scores has been reported on the STOE subscale (Lockman 2006). Nevertheless, multiple cohort research designs strengthen arguments for covariant relationships between teachers’ science teaching efficacy growth and participation in science professional development. Such approaches make rich contributions to the STEBI-A literature by helping to rectify some of the issues associated with the absence of true experimental designs.

Some research at this level presented merged STEBI-A subscales. The choice to merge the subscales prevents between studies comparisons but the research provides some notable standalone information. Nadelson et al. (2013) used a merged science teaching efficacy belief score, amongst other measures, to evaluate the impact of an inquiry-based STEM professional development program. They reported on two separate offerings of the program over two years, with the first cohort providing data in year one and the second cohort providing data in year two. The first cohort showed a large overall STEB change (Cohen’s $D = 0.923$). The second cohort displayed only moderate STEB growth (Cohen’s $D = 0.452$). Both groups reported improved attitudes towards STEM and greater science teaching confidence. Perhaps most importantly, many of the 68 teachers displayed a heightened inclination to incorporate STEM concepts in their classroom curricula. Ellins et al. (2013) describe a 5-year teacher professional development program entitled “The Texas Earth and Space Science (TXESS) Revolution”. Participating secondary science teachers were provided with mentoring, curriculum support and workshops to develop their geoscience pedagogical content knowledge. The participants reported greater geoscience content knowledge and increased confidence for the classroom use of technology. The STEBI-A use was problematic as
the subscales were merged and the broad mean scores were not differentiated for the 3 iterations of the program. Nonetheless, the teachers’ science teaching efficacy beliefs did not display significant growth. There were 11 research items that reported on pre- and post-test data from multiple cohorts. 22 articles progressed to the next level of research design analysis.

**Longitudinal Quasi-Experimental Research Designs (3)**

Longitudinal STEBI-A research has been used to elucidate the, often overlooked, experiences of early career teachers as they transition from pre-service to in-service status. Wingfield et al. (2000) used a longitudinal design to determine if pre-service science teaching efficacy beliefs were maintained through the first year of in-service teaching. The results indicated that the PSTE and STOE growth which occurred within the 31 participants of a site-based tertiary science program remained durable after their first year of in-service teaching. Similarly, Palmer (2011) found that the strong PSTE effect size gains made by pre-service teachers, who participated in a science intervention, incorporating cognitive mastery, enactive mastery, modeling and verbal persuasion, remained durable for two years after the conclusion of the intervention. It is important to recognize that school variables can potentially confound the durable efficacious impacts of tertiary science interventions. Andersen et al. (2004) collected longitudinal STEBI-A data from 66 Danish elementary teachers at the beginning, middle and end of their first year of teaching in order to determine how their science teaching efficacy beliefs were influenced by teaching environment variables. Analyses showed that there was a relationship with participants’ PSTE scores and their beliefs about their school science contexts. This relationship is of particular interest as the first year teachers showed small decreases in their PSTE scores (Cohen’s D = -0.36). This may be construed as evidence for a negative science culture existing at the elementary school level.

Longitudinal STEBI-A research designs have been used to evaluate established ongoing science professional development programs. A group of 12 teacher leaders received a combination of content instruction, problem-based Science instruction and leadership instruction over a 3-year period (Menitzer et al. 2014). At the completion of the study, the teacher leaders reported statistically significant increases in their science content knowledge and science teaching outcome expectancy scores. The stagnation of the PSTE scores defies broader trends within the STEBI-A literature. Ulmer et al. (2013) found that an integrated Agriculture professional development program, with a focus on curriculum development, seemed to produce results that aligned more closely with the common tendencies in the STEBI-A literature base. The large PSTE effect size gains (Cohen’s D = 0.958) remained durable after the program had ended. The STOE effect size increases were not durable as the final scores were not significantly different from the pre-test scores. In a comparable study, Sandholtz and Ringstaff (2014) collected data over a 3-year period to assess the impact of a research-based science content
course on 39 K — 2 teachers. The authors reported strong, durable increases to both the PSTE and STOE scores of the participants. However, these findings could not be verified as the descriptive statistics were omitted from the article. There were 8 research articles remaining after the previous 14 were removed.

Experimental Research Designs (4)

The remaining 8 research items employed approximate experimental research designs. That is to say that both experimental and control groups were clearly identified. It should be noted that random group assignment was not always a feature of the research described at this level. McConnell et al. (2008) employed an experimental design to determine if video-based reflective practices enhanced teachers’ capacity to make evidence based decisions relating to their practice and improved their science teaching efficacy beliefs. The experimental group showed greater improvements in their science teaching efficacy beliefs and showed more scepticism toward memory-based reflection as they began to favour evidence-based reflection to inform pedagogical choices. In fact, while the experimental group showed large effect size increases (Cohen’s D = 0.98) to their PSTE scores, the control group showed moderate declines on the same subscale (Cohen’s D = −0.63). The generalisability of these STEB-A data are limited by the total sample size of 15 participants. This research could therefore not be considered in other sections of this review. Sang et al. (2012) investigated the modality of professional development delivery in a randomly grouped, experimental research project. The experimental group participated in a 10-week constructivist science program that required deep analysis of video-taped science lessons from novice and expert science teachers. The control group provided the same pre- and post-test data but did not undertake an intervention. The experimental groups showed moderate PSTE increases. Resentful demoralisation may have hindered the validity of the research as the control group displayed statistically significant declines on both the PSTE and STOE subscales. The implication may be that alternate interventions in a modified experimental design may be more appropriate for STEBI-A research than a control group experiencing no intervention because of the expectations and perceptions of participants. Fishman et al. (2013) overcame such difficulties by delivering similar professional development experiences with the key differentiating variable of delivery method. A total of 49 secondary teachers were assigned to either face-to-face or online delivery groups of an inquiry-based environment science professional development program. Regression analyses showed that there were no significant differences on science teaching efficacy between groups. Cohen’s D effect sizes could not be calculated due to the absence of key descriptive statistics. The following section will analyse the use of the PSTE and STOE subscales within the STEBI-A literature.
The PSTE and STOE Subscales Within the STEBI-A Literature

There appears to be some inconsistency in the usage of the subscales within STEBI-A literature. The STEBI-A subscales were used explicitly in 80 of the analysed research items. The PSTE subscale was used on all such occasions. Merging subscales and STOE omission were seen within the STEBI-A literature. Despite the complementary and separate nature of the PSTE and STOE subscales (Riggs and Enochs 1990), the two were merged in 14 research projects. Several of these research items recognised the different subscales but choose to provide merged means (e.g., Buyuktaskapu 2010; Ogbomo 2010; Saka 2007). More commonly, paired T-tests have been used to explore changes in participants’ responses to individual items over time (e.g. Duran et al. 2009; Kuchey et al. 2009; Sandholtz and Ringstaff 2011). Such approaches allow for analysis of the deeper variables that contribute to the STEB constructs but hinder comparisons between research items from different contexts. In 20% of the relevant articles the STOE subscale was simply omitted entirely. The choice to avoid the STOE subscale has become more prominent in the past decade as the 12 of the 16 articles/dissertations that fulfil this criterion have emerged after 2005 (e.g., Khourey-Bowers and Fenk 2009). The implications of the decline in STOE usage will be unpacked in the discussion. The relative difficulty in affecting STOE growth may be a factor in choices to avoid the subscale.

Within the STEBI-A literature teachers commonly show higher scores on the PSTE scale. Three quarters of the STEBI-A research makes clear distinctions between the reporting of PSTE and STOE results, thus allowing for clearer inter-research comparisons. In fact, there were 64 research items that accurately measured both the PSTE and STOE scores of the research participants. A total of 38 research items presented the data in a way that allowed for PSTE mean scores to be compared with STOE mean scores on at least one occasion (cross sectional). A clear majority (82%) of these research items reported that the PSTE scores of participants were significantly higher than their STOE scores. This trend may be related to the higher number of latent variables, such as other teachers and school contexts, which can influence the STOE subscale. It is concerning that teachers’ perceptions of their own capacity to deliver quality science teaching experiences are higher than their own expectations of science teaching outcomes in a general sense. These trends may hint at an unnerving cynicism within science teachers.

There were 24 examples of research where the growth rates of the subscales were comparable. This number is significantly less than the 65 articles that fulfilled these requirements in the STEBI-B review in Chap. 1. This may hint at the relative difficulty in obtaining consistent participant samples from populations of practicing teachers. Figure 3.3 shows the trends in STOE subscale growth for the STEBI-A instrument. The PSTE subscale displays more capacity for development, as 65% of the analysed research items reported higher growth rates on the PSTE subscale. Higher STOE growth was reported in 25% of the research projects,
indicating that the STOE may be malleable for in-service teachers. This is up from 15% reported for the STEBI-B instrument. The implications of this finding will be explored in the discussion section of this chapter.

There were two research items that reported comparable effect size gains on both subscales. McConnell et al. (2008) found that the use of video-recording as a tool for teacher reflection on science practice caused 1-sigma growth in both PSTE and STOE scores. Through the use of a retrospective post-pre-test, quasi-experimental design, Ulmer et al. (2013) found that participants in a problem-based agricultural professional development program displayed large gains in both PSTE and STOE scores. Curiously, a nine month follow up revealed that the PSTE gains were not sustained whilst the STOE gains proved unsustainable. Nevertheless, the core message remains true in a sense as in-service teachers, much like their pre-service counterparts, generally feel more confident in their personal science teaching ability than they do in the capacity of science teaching to improve students’ knowledge and skills.

**Innovative Practices Within the Science Interventions**

There were 76 STEBI-A research publications that noted the inclusion of a science intervention in the body of the writing. Of these articles and dissertations, six did not include sufficient description to allow for intervention coding. The remaining 70 articles were coding dichotomously as either including or not including each of the 16 identified innovative practices. Tertiary partnerships and school partnerships were included to account for the in-service context. The raw numbers for each innovative practice are presented in Fig. 3.4. The average science program included 4.6 innovative practices, indicating that many innovative practices are being combined to create intricate educational designs.

The most frequently identified innovative practices were inquiry learning (64%), cooperative learning (52%) and curriculum development (38%).
This suggests that the professional development programs are tailored to suit the practical needs of practicing teachers. There were no innovative practices that were definitively absent from the coded science programs, indicating that science professional development may be more varied and reflexive than the science interventions offered to pre-service teachers at the tertiary level. Tertiary partnerships (43%) and mentoring/in-school support (34%) indicate that deeper, long-term programs are being delivered to account for the professional needs of in-service teachers. The researchers are recognising the potential benefits of participants’ immediate access to appropriate elementary and secondary class groups. Such rich links to practical teaching opportunities are inherently more difficult to establish with pre-service teachers who often do not have access to a regular class.

When considering the innovative practices used within science professional development programs it is crucial to recognise the differences between pre-service and in-service teaching contexts. The aforementioned access to school contexts is an unquestionable advantage for the delivery of in-service science professional development, but there are difficulties that instructors need to overcome that are not as common in the tertiary context. The dispersal of in-service teachers amongst schools in combination with the professional requirements of the teaching profession makes it more difficult to contact and work with in-service teachers. To determine how professional development programs accounted for time restrictions, financial issues and geographic dispersal, all 69 interventions were coded based on both the type and length of program delivery. There were 66 programs that clearly stated the type of delivery. Each program was codes as either online, face-to-face or mixed. Face-to-face delivery was described in 53 articles (80%), an understandable finding given the age of the STEBI-A instrument. Curiously, only two articles described an online delivery, one of which was
published in 1996 (Shroyer et al. 1996). A new trend of mixing online and face-to-face learning opportunities appears to be emerging in the STEBI-A literature as 8 of the 11 programs that utilised this mixed approach were published after 2010. Online and mixed deliveries of professional development could play a role in addressing the disadvantages of those teachers in more isolated/rural school locations. 63 articles and dissertations were coded based on length of the professional development programs described (single contact, multiple contacts and multiple contacts with imbedded in-school follow ups). A promising finding was that only five programs described one contact session. The majority of professional development programs (54%) incorporated multiple contact sessions for instructors and participants. 24 programs included follow-up school visits, reflections and/or clear links back to professional practice. Such trends may not be representative of science professional development as the coded programs have been taken from published research.

**The PSTE and STOE Effect Sizes Produced by Science Interventions**

Research reporting on data from less than 21 participants was removed from this section of the analysis. This ensures that statistical assumptions for the data set can be met as the pre- and post-test scores for each calculated effect size should have a relatively normal distribution of scores with minimal skewing. A total of 21 pieces of research were deemed suitable for PSTE and STOE subscale analysis. Figure 3.5 shows the distribution of effect sizes reported on both the PSTE and STOE subscales. The red lines differentiate insignificant, small, moderate, large and very large effect sizes. There is not a normal distribution of scores for either

![PSTE and STOE distribution histogram](image)

**Fig. 3.5** PSTE and STOE distribution histogram
subscale. The high Kurtosis of both the PSTE (4.831) and STOE (9.737) subscales indicates that the spread of scores is notably separate from the mean point. When the extreme outliers are removed these Kurtosis scores drop to 1.927 and 2.256 respectively. The PSTE subscale has produced greater growth with many moderate to large effect sizes reported. The majority of STOE effect sizes are insignificant to small. This reflects the issues with the measurement and improvement of the STOE subscale that are rife within the STEBI-A and STEBI-B literature.

There is a significant difference between the mean PSTE and mean STOE effect sizes reported within the STEBI-A literature. The descriptive statistics for the subscale effect sizes are presented in Table 3.3. The mean PSTE effect size is greater than the mean STOE effect size. When the outliers are removed from the data set this gap widens as the mean PSTE effect size (0.77) is three times larger than the almost insignificant mean effect size (0.205) of the STOE subscale. The disparity may be larger as six studies that measured the growth of the PSTE subscale did not report on the STOE subscale scores. Simply put, there may be lower STOE effect sizes that are not presented in the STEBI-A literature. The subscale differences reflect the aforementioned disparity in the subscale mean scores where the STOE shows lower mean scores and an elevated propensity for stagnation. The discrepancy between the subscales closely resembles the trends within the STEBI-B literature.

The mean score and effect size differences between the PSTE and STOE subscales are reinforced by correlation analysis as a significant negative or positive correlation does not exist between the efficacy measures. Table 3.4 presents the output for the PSTE and STOE effect size correlation analysis. The correlation analysis suggests that there is almost no correlation between PSTE and STOE effect sizes (Pearson’s R = 0.121). This result is notably different from the STEBI-B analysis, which showed a moderate-to-strong correlation between the subscale effect sizes (Pearson’s R = 0.628). The small sample size of relevant effect size data for the STEBI-A analysis may be a factor in this result. The result itself may suggest that the PSTE and STOE constructs separate further when

| Table 3.3 Descriptive statistics for PSTE and STOE effect sizes |
|------------------|------------------|----------------|
| Mean             | Std. deviation   | N               |
| PSTE Mean        | 0.572            | 0.757           | 21              |
| STOE Mean        | 0.398            | 0.817           | 15              |

| Table 3.4 Correlation analysis for PSTE and STOE effect sizes |
|------------------|------------------|----------------|
|                  | MeanPSTE         | MeanSTOE       |
| PSTE Mean        | Pearson correlation | 1           | 0.121*          |
|                  | Sig. (2-tailed)  | 0.667          |
|                  | N                | 21             | 15              |
| STOE Mean        | Pearson correlation | 0.121*        | 1               |
|                  | Sig. (2-tailed)  | 0.667          |
|                  | N                | 15             | 15              |

*Correlation is significant at the 0.05 level (2-tailed)
pre-service teachers graduate and enter the teaching profession. Certainly, experienced teachers have access to a wider variety of experiences and perspectives that can affect their general outcome expectancies. The limited sample of research prevents definitive statements being made here. The following paragraphs will rank the PSTE and STOE effect sizes produced for in-service teachers and broadly describe the pedagogical themes. Due to the low number of articles, the top 5 PSTE and STOE research projects will be presented and discussed. This prevents insignificant STOE effect sizes from being presented.

The innovative practices used by the top five science interventions based on PSTE effect sizes produced mirror the trends within the wider body of coded science programs. Inquiry learning (3), teaching experiences (3) and curriculum development (2) were the most common innovative practices amongst this group. Table 3.5 ranks the top research pieces on PSTE effect sizes produced. A curious finding was that none of the 5 research projects featured a tertiary partnership as an overt programmatic inclusion. This could be hinting at recognition of the differing needs of pre-service and in-service teachers. It may also be related to the practical issues associated with delivering professional development through a tertiary institution. The complexity of the research designs is lower amongst this group, with an average of 4 innovative practices compared to the mean of 4.6 amongst all coded science interventions. Perhaps the demands of in-service teaching call for clearer and deeper science interventions.

All of the top 5 PSTE interventions reported strong effect size increases within participants. Roberts et al. (2001) collected data over an 8-year period to assess how different delivery timeframes influenced the personal science teaching efficacy beliefs of over 300 teachers. The program employed a constructivist approach to enhance participants’ understanding of inquiry pedagogies. They were also afforded practical teaching opportunities and mentoring sessions with experienced science teachers and scientists. A large PSTE effect size (Cohen’s $D = 1.3$) was reported across the four groups. An interesting finding was that a four week delivery period produced the greatest PSTE gains, with longer periods leading to diminished results. This information directly contradicts the

<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Innovative practices</th>
<th>Effect size</th>
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</thead>
<tbody>
<tr>
<td>2003</td>
<td>Eshach</td>
<td>Problem-based learning, curriculum development, inquiry learning, cooperative learning</td>
<td>1.3</td>
</tr>
<tr>
<td>2001</td>
<td>Roberts, Henson, Tharp and Moreno</td>
<td>Constructivism, mentoring/ta-school support, inquiry learning</td>
<td>1.3</td>
</tr>
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<td>2002</td>
<td>Posnanski</td>
<td>Modelling and vicarious experiences, deep links to mathematics (STEM), field experiences, curriculum development, inquiry learning, school partnership</td>
<td>1.045</td>
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<tr>
<td>2013</td>
<td>Batiza et al.</td>
<td>N/A—Deep content focus</td>
<td>1.03</td>
</tr>
<tr>
<td>2001</td>
<td>Kean and Enochs</td>
<td>Field Experience, mentoring, site based learning, tertiary partnership, cooperative learning, ICT instruction, student-centred investigation</td>
<td>0.95</td>
</tr>
</tbody>
</table>
findings of Posnanski (2002). Posnanski described a detailed and scaffolded science program wherein practicing teachers attended 3–4 h weekly meetings over a 32-week period. The participants developed science programs, STEM knowledge, and a repertoire of inquiry pedagogies. The practices were incorporated into a reflective framework where participants’ previous practices were critiqued and adjusted, rather than dismantled. This ultimately culminated in a large PSTE effect size growth (Cohen’s $D = 1.045$) for the 31 teachers. The creators of the Students Understanding Energy (SUN) project eschewed pedagogical variance for comprehensive coverage of core science content knowledge (Batiza et al. 2013). Teachers developed their capacity to teach biological energy transfer through hands-on, model building experiences. The participants displayed durable improvements in both their content knowledge scores and personal science teaching efficacy beliefs. Kean and Enochs (2001) found that participation in a 3-week Geology workshop, incorporating student-centred investigation and curriculum development opportunities, covaried with large effect size increases in participants’ PSTE scores. The next paragraph describes the pedagogical trends amongst the top five STOE interventions.

There were no consistent pedagogical trends amongst the science interventions that showed the greater effects on participants’ science teaching outcome expectancies. Table 3.6 ranks the top five interventions in terms of STOE effect sizes produced. The most common innovative practices amongst these interventions were cooperative learning (4) and inquiry learning (4). None of the five interventions incorporated practical teaching experiences. The mean number of innovations (4) was slightly smaller than the mean for all 70 coded interventions (4.6). Perhaps clear, deep science interventions are more appropriate for in-service teachers than complex, pedagogically diverse programs. Deeper research, beyond the constraints of this review, is required to develop a clearer understanding of how the STOE effect sizes of in-service teachers can be improved. While the dichotomous coding and effect size calculation provide a summary of the effectiveness of science

<table>
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<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Eshach</td>
<td>Problem-based learning, curriculum development, inquiry learning, cooperative learning</td>
<td>3.15</td>
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<tr>
<td>2013</td>
<td>Ulmer and others</td>
<td>Student-centred investigation</td>
<td>0.806</td>
</tr>
<tr>
<td>2011</td>
<td>Holden, Groulkh, Bloom and Weinbrugh</td>
<td>Constructivism, site-based learning, cooperative learning</td>
<td>0.557</td>
</tr>
<tr>
<td>2010</td>
<td>Gosselin et al.</td>
<td>Constructivism, site-based learning, inquiry learning, tertiary partnership, cooperative learning, ICT instruction, authentic learning, nature of science focus</td>
<td>0.41</td>
</tr>
<tr>
<td>2010</td>
<td>Shin et al.</td>
<td>Problem-based learning, mentoring, inquiry learning, cooperative learning, alternative conception targeting</td>
<td>0.383</td>
</tr>
</tbody>
</table>

*Denotes outlier
interventions, variables such as the teacher, the pedagogical combinations and the teaching contexts of participants need to be given further consideration.

Amidst the widespread struggles to affect change on the STOE subscale, Eshach (2003) reported on a series of inquiry-event based science workshops that produced gargantuan STOE effect size growth (Cohen’s D = 3.1) that has never been replicated. The inquiry events required the participants to engage in focused scientific research which was explicitly linked to common community issues. Clearly, developing teachers’ understandings of the nature of science and its place in society through successful scientific investigative experiences can improve their science teaching outcome expectancies. Perhaps understanding the nature of science is needed to influence the STOE subscale more so than pedagogical and content development. Ulmer et al. (2013) described an investigative science professional development program where the learning experiences were framed by problem-based learning scenarios. The 88 participating teachers were provided with agricultural science curriculum materials to use within their classrooms. Initial results showed that the participating teachers experienced large STOE growth (Cohen’s D = 0.806). However, these gains were not durable as their STOE scores had returned to pre-intervention levels just nine months after the conclusion of the program.

More pedagogically diverse programs have shown to covary with moderate STOE effect size gains for participants. Gosselin et al. (2010) investigated the influence of the Laboratory Earth science professional development program. The complex online program used cooperative learning strategies to guide inquiry learning opportunities. The program afforded participating teachers the opportunity to establish links with the scientific community to help them better understand the nature of both science and investigation. The 51 participants reported improved content knowledge and greater enjoyment of science teaching. Their outcome expectancy beliefs showed statistically significant, albeit small-to-moderate, effect size increases. Shin et al. (2010) reported on a similarly supportive long-term professional development program that utilized reflexive face-to-face workshops rather than online study modules. The innovative practices included: problem-based learning, mentoring, inquiry learning, cooperative learning and misconception targeting. The three cohorts display improved science teaching pedagogical repertoires and small-to-moderate STOE increases (Cohen’s D = 0.393). The following section will discuss and analyse some of the more prominent findings that emerged from this STEBI-A review.

**Discussion**

The STEBI-A instrument has been adapted for a variety of compelling research purposes since it was developed and published by the seminal authors (Riggs and Enochs 1990). A simple analysis of the literature in terms of the number of STEBI-A administrations with each research project shows a relatively even spread
of research approaches, with 40% of research reporting one use, 23% reporting
two uses and a further 37% reporting more than two uses of the instrument. The
instrument has been used to: conduct deep case study research (Nafziger 2008);
target research participants (Ramey-Gassert et al. 1996); make comparisons with
student variables (Saam et al. 1999); explore relationships between STEBs and
science content knowledge (Lekhu 2013); assess the influence of professional
development programs (Nelson 2006); and determine the durability of efficacious
change (Sandholtz and Ringstaff 2011). The STEBI-A instrument has had, and
continues to have, a lasting impact as a means of consistently measuring efficacy
constructs in a field with inherently intangible variables. The STEBI-A instrument
has also played a role in the globalisation of science teacher research as nations
such as China, Ecuador, The Netherlands and The United Arab Emirates have all
contributed to the body of literature within the past five years. Researchers are
making strides to capture strong samples of in-service teachers as there was an
average of 80 participants per research project. The average only dropped to 65
when the cross sectional and qualitative research was removed. There are still some
issues with sampling for research designs with multiple STEBI-A administrations.

Some contextual and methodological issues have emerged from within the
STEBI-A literature base. Factors such as: small sample sizes (e.g. Britton 2013),
subscale merging (e.g. Rudman and Webb 2009), STOE omission (e.g. Clark
2009) and unclear descriptive statistics serve to mitigate the comparisons of
research across different contexts. A number of strong research projects were
eliminated at the effect size stage of the analysis because the low number of par-
ticipants meant that key statistical assumptions could not be met (e.g. McConnell
et al. 2008; Mentzer et al. 2014). The limited generalisability of low participant
numbers is also an issue for the research that aims to bridge gaps between in-
service and pre-service teaching. There are few examples of research that follow
the science teaching efficacy beliefs trends in a statistically generalisable fashion.
The STEBI-A literature needs to continue to shift from an exploratory focus to
an evaluative focus. That is to say that, due to the declining state of science edu-
cation globally, research needs to consider how science teaching efficacy deficits
can be addressed. The use of evaluative research designs with multiple STEBI-A
administrations, is a viable and comparable method of assisting the literature in
developing along such a pathway. Admittedly, problems with consistent access to
teacher data and issues with resentful demoralisation occurring in true experi-
mental designs could hinder such progress. Resentful demoralisation could poten-
tially be addressed by offering modified interventions, rather than no interventions, for
control groups (e.g. Fishman et al. 2013).

The PSTE and STOE subscales are generally applied consistently throughout
the STEBI-A literature. The PSTE subscale is commonly favoured over the STOE
subscale due to its higher reported reliability (Yang et al. 2014) and greater capacity
for growth (e.g. Haney et al. 2007). The STOE subscale has similar issues in
the STEBI-A literature as are shown in the STEBI-B literature. The STOE sub-
scale is commonly merged inappropriately with PSTE items (e.g. Shea et al. 2013)
or omitted entirely from research (e.g. Lucero et al. 2013). When the STOE subscale is measured accurately, it commonly produces lower mean scores (e.g. Liu et al. 2008) and shows less growth (e.g. Ulmer et al. 2013) than the PSTE subscale. In fact, there was a notable trend of small declines in teachers’ STOE scores within the STEBI-A literature (Haney et al. 2007; Lockman 2006; Saka et al. 2009). Compelling arguments against the STOE subscale have been made, based on issues such as low reliability (e.g. Nelson 2006), the external locus of construct influence (e.g. Lardy 2011) and even the lack of consistency in how the subscale should be interpreted (Roberts et al. 2001; Settlage et al. 2009). Such arguments have undeniable merit but the outcome expectancies of teachers still need to be considered and addressed. In a practical sense, an individual teacher cannot be extrapolated from the broad social, cultural and socio-economic contexts within which they practice. Without a sufficient belief that potentially detrimental factors can be overcome by science teaching in general, a teacher is less likely to show resilience in challenging professional situations. Therefore, it is inappropriate and short-sighted to place greater emphasis on teachers’ personal science teaching efficacy over their more general outcome expectancies.

The conceptual separation of the PSTE and STOE subscales is a key point of differentiation between the STEBI-B and STEBI-A literature. It appears as though the correlation between the PSTE and STOE subscales declines with teaching experience. For the STEBI-B instrument there was a moderate-to-strong correlation between the PSTE and STOE effect sizes produced within research projects (Pearson’s R = 0.628). However, there was no correlation between the PSTE and STOE effect sizes produced in the STEBI-A research (Pearson’s R = 0.121). An interpretation may be that entering the teaching profession serves as a catalyst for a conceptual separation of the PSTE and STOE subscales. This is not the first separation of the STEBI-A subscales that has been noted in the literature. Desouza et al. (2004) found that the correlation between the subscales weakened as the level of teacher education attainment increased. One may consider this a process of natural maturation as individuals move from idealistic to realistic conceptualisations of science teaching. If anything, this subscale separation affirms the importance of tertiary science education in establishing core science teaching efficacy beliefs. It also hints at the differing needs of pre-service and in-service teachers. Curiously, there is some evidence that the STOE subscale could be more malleable for in-service teachers as a greater proportion of the STEBI-A literature reports higher growth than the STEBI-A literature. Raising outcome expectancies, adapting to and considering the professional contexts of teachers and explicit consideration of extraneous teaching variables could be used within science teaching professional development programs.

The practical needs of teachers are evident in the pedagogical inclusions within the analysed science programs. Inquiry learning, cooperative group work and curriculum development were the most common pedagogical inclusions amongst the 76 coded science programs. Each of the other innovations was represented within the literature. The same teacher-centred, practical approaches were evident in the
interventions that covaried with the strongest PSTE and STOE effect size gains. The mean effect size gain for the PSTE subscale (Cohen’s D = 0.572) was notably, if expectedly, larger than the mean effect size gain on the STOE subscale (Cohen’s D = 0.398). Curiously, despite the aforementioned separation of the subscales, there were no key pedagogical differences between the top interventions in terms of PSTE and STOE growth. The absence of significant STOE gains throughout the STEBI-A literature more broadly, dilutes the comparison between the subscales in terms of pedagogical influence. There was a slight trend toward less complex program designs with fewer innovative practices. Perhaps clearer program designs account for the need of practicing teachers to balance their professional practice with participation in science professional development. Concerted efforts are being made to overcome issues stemming from difficulty in accessing and supporting in-service teachers. Since 2010 eight programs have incorporated online elements as a means of supplementing traditional face-to-face deliveries (e.g. Sung et al., 2012).

There are a number of implications that have arisen from the findings of this comprehensive STEBI-A review. Firstly, the STEBI-A literature needs to continue to shift from an exploratory focus to an evaluative focus due to the waning state of science education globally. More research with multiple administrations of the STEBI-A instrument and sufficient participant samples is needed to assess the influence of different pedagogical approaches on in-service teachers’ science teaching efficacy beliefs. This is particularly important given the differences between the needs of pre-service and in-service teachers. Secondly, the conceptual separation of personal science teaching efficacy and the more general outcome expectancies that appears to be evident for in-service teachers indicates that different approaches to science professional development are needed. When considered in conjunction with the noted stagnation of the STOE scores, it appears that the specific teaching contexts and beliefs of practicing teachers need to be overtly considered in more reflexive approaches to science professional development. Thirdly, the complementary nature of the STEBI-B and STEBI-A instruments affords a unique opportunity for statistically valid and reliable tracking of prospective teachers’ science teaching efficacy beliefs as they transition into their professional teaching careers. There needs to be more research conducted to determine if gains to teachers’ science teaching efficacy made at the tertiary level remain durable after graduation. Currently, this transition has only been covered in a qualitative manner (e.g. Saka, 2007). Finally, online delivery and support for science professional development programs need to be addressed within the STEBI-A literature. Distance support is a viable means for remediating the issues of access and time restrictions that are specific to in-service teachers. In conclusion, the STEBI-A continues to be a valid and reliable instrument that can provide contextually transferable data and insights in an area of science education where effects and changes are difficult to identify and measure.
References


Chapter 4
Conclusion

The analytic framework presented in this Springer Brief has allowed for the deep and systematic analysis of over 240 articles and dissertations which have used the Science Teaching Efficacy Belief Instruments (A-B) over the past 25-years. The separate analyses of research methods and findings has allowed for the relatively objective critique and organisation of a large (combined citation score of 1400) and rapidly growing body of literature. While the increasing availability of online publication platforms has enhanced the sum of science education knowledge, it presents new challenges to modern education researchers as they strive to reconcile their own work within increasingly expansive fields of research. Thus, it stands to reason that meta analytic and review research will need to be conducted to ensure the research community continues to respond to appropriate gaps in knowledge based on changing needs, to ultimately affect positive change in science education. The need for the critique and summary of burgeoning literature bodies extends to other fields of science education and, indeed, educational research in general. Aside from providing a thorough critique and organised summary of the STEBI-B/A literature bodies, it is hoped that the analytic framework presented in this Springer Brief can serve as a model for future review research in other domains. At the very least, the reader should spare a thought for the PhD candidates, teachers, policy makers and educational administrators who are likely to be overwhelmed by the increasing permeation of valuable education research.

The STEBI-B instrument has been used in varied ways to advance science education research. The United States of America, Australia and Turkey are the current global leaders in the production of STEBI-B research with increasing contribution rates from other nations. The STEBI-B research methods are similarly diverse. Qualitative STEBI-B research has served to establish the importance of teacher efficacy in science education. Tosun (2000) modified the STEBI-B instrument to create interview questions for 17 pre-service teachers. Participants’ responses to their tertiary science experiences were overwhelmingly negative, despite notable differences in achievement scores. This indicates that teachers’ feelings towards science may overshadow academic achievement in terms of influence on science teaching efficacy beliefs. A similar qualitative study revealed
that pre-service teachers place a greater emphasis on “fun” rather than academic rigour when selecting and developing science lessons (Peters-Burton and Hiller 2013). Cross sectional research indicates positive correlations amongst pre-service teachers’ science teaching efficacy beliefs and other variables, including: classroom management beliefs (Gencer and Çakiroğlu 2007), epistemological views (Yilmaz-Tuzun and Topcu 2008) and science content knowledge (Sarikaya et al. 2005). In recent years, more complex research designs, with multiple STEBI-B administrations, have been used to assess the efficacy of different approaches to tertiary science education. Results have indicated approaches such as curriculum development (Jabot 2002), mentoring (Cooper 2015), cooperative learning (Palmer 2006), in-subject practical teaching experience (Bautista 2011) and links to extended professional placement blocks (Swans and Dooley 2010) can all be viable ways of enhancing the science teaching efficacy beliefs of prospective teachers. There is now overwhelming evidence to remove transmissive, disengaging, content-heavy approaches from pre-service science education programs and courses.

The STEBI-A literature exhibits similar variance in terms of methodologies and findings. Most of the research originates from the USA with a small, but meaningful, group of contributions emerging from other nations. Modified, qualitative use of the STEBI-A has deepened our understanding of science teaching efficacy, relevant antecedents and teachers’ science teaching experiences. In fact, qualitative STEBI-A research has highlighted the influence of school contexts on teachers’ science teaching efficacy beliefs (Gins and Watters 1996) and the apparent dissonance between tertiary education messages and professional teaching contexts (Saka 2007). Such antecedents will undoubtedly inform new STEBI research. Cross sectional STEBI-A research has broadened the relevance of science teaching efficacy by establishing links to: the use of constructivist teaching practices (Burton 1996), preferences for affording student autonomy (Lucero et al. 2013), and the time spent teaching science (Albion and Spence 2013). A significant section of quasi experimental STEBI-A research has provided empirical evidence to prove the worth of approaches such as inquiry learning (Eshach 2003), mentoring/in-school support (Roberts et al. 2001), curriculum development (Posnanski 2002) and tertiary partnerships (Kean and Enochs 2001) for improving the science teaching efficacy beliefs of in-service teachers. While there is a predictable reliance on face-to-face modes of communication across the analysed professional development programs, many practitioners and researchers have addressed issues of time and geographical disparity through in-school follow up visits and opportunities for general course reflection (Shin et al. 2010). In recent years, online learning has become a more prominent inclusion within science education professional development programs as a means of fostering more direct communication between instructors and in-service teachers (Blackmon 2003; Haesler and Lozamowski 2010; Sang et al. 2012). Diverse, learner-centred programs as such “Primary Connections” (Hackling 2006) and “Science by Doing” (Rennie 2010) are examples of beneficial changes that are occurring within the field of in-service science teacher education.
STEBI analyses revealed several similarities between pre-service and in-service teachers. In terms of science education program design, there are no clear differences between pre-service and in-service teachers in the innovative practices that have shown to covary with increased science teaching efficacy beliefs. After 25-years of global STEBI research, there is ample evidence for the use complex, cooperative and learner-centred practices for science teacher education (Lumpe et al. 2012; Palmer 2006). Many prospective and practising teachers have reported greater increases to their personal science teaching efficacy belief scores (Bautista and Boone 2015; Nelson 2006), even though the PSTE subscale has shown to produce consistently higher mean scores than the Science Teaching Outcome Expectancy (STOE) subscale (Bautista 2011; Saint 2013). Some disparity between the subscales is to be expected given the general, more open nature of the STOE subscale. However, this does not remove the onus on instructors and researchers to improve the science teaching outcome expectancies of in-service and pre-service teachers alike. At the very least, the reported decreases in teachers’ STOE scores need to be considered in the development of future science programs and research projects (Haney et al. 2007; Saka et al. 2009).

The key point of difference between pre-service and in-service teachers is the relationship between personal science teaching efficacy (PSTE) beliefs and science teaching outcome expectancies (STOE). Analysis of STEB effect size changes shows that there is a moderate-to-strong correlation (Pearson’s R = 0.628) between the subscales for pre-service teachers. Curiously, there is no such correlation between the PSTE and STOE growth scores of in-service teachers (Pearson’s R = 0.121). When considered in conjunction with the noted challenge of improving the STOE of practicing teachers (Blackman 2003; Ewing-Taylor 2012) it would seem that the transition from pre-service to in-service status serves as a catalyst for the separation of the subscales. Such a trend seems unavoidable as school contexts introduce powerful antecedent variables (e.g. colleagues, parents, administrators, etc.) that will likely influence the outcome expectancies of in-service teachers. This is not a new finding as prior research has shown the correlation between the STEB subscales declines as levels of education qualifications increase (Desouza et al. 2004). Perhaps this efficacious separation is related to a process of professional maturation wherein teachers move from idealistic notions of science teaching to hold more realistic, grounded perceptions of the value of science teaching. Still, a portion of the STEBI-B research has shown that preparatory science programs can improve the STOE of pre-service teachers (Cooper 2015; Ozdelik and Bulunuz 2009; Templeton 2007). Tertiary science education programs must play a key role in improving pre-service teachers’ science outcome expectancies to ensure their resilience when faced with potentially detrimental extraneous variables in professional school contexts.

There are a number implications for future research which have emerged from the STEBI-B and STEBI-A reviews contained within this Springer Brief. First, despite the widespread permeation of STEBI research over the past quarter of a century, there are relatively few examples of research using both instruments in a complementary fashion to investigate teachers’ transitions from pre-service to
in-service status (McKim and Lamberts 2013). Such transitional phases represent an open and promising area of science education research. Of particular note is the apparent dissonance between the positive growth trends reported in the tertiary science domain (Bautista 2011; Palmer 2006) and the continued negative reports of teacher attitudes (Jarrett 1999), transmissive pedagogies (Jarvis and Pell 2005), student disengagement (Dewitt et al. 2014) and student achievement (Thomson et al. 2008, 2011). Second, more complex STEBI research designs are needed to assess the durability of STEB changes reported during science interventions. The STEBI instruments have already been used to: explore the nature of science teaching efficacy in individual contexts (Mulholland and Wallace 2003), assess the relationship between science teaching efficacy and other relevant variables (Enochs et al. 1995) and evaluate the impact of innovative approaches to science education (Jabot 2002). Thus, the next logical steps would be to assess the durability of science teaching efficacy growth and, ultimately, explore how science teaching efficacy and science education experience influence classroom teaching practice. Third, the established nature of the STEBI literature base should allow for more connections between different sub-domains within the literature itself. For example, the global use of the STEBI instruments affords the opportunity for rich international research collaboration (Çakiroğlu et al. 2005; Rogers and Watters 2002). Fourth, STEBI researchers should begin to consider the modes through which science interventions are delivered. Admittedly, face-to-face education was the deserved focus when the STEBI instruments were published in 1990. However, science education programs are using online and blended modes of delivery at higher rates than ever before (Goselin et al. 2010; Kean and Enochs 2001). Yet the impact of online and blended modes of delivery on participants’ STEBIs is still largely unknown. Finally, review research needs become more prominent within science education as rates of research production continue to increase.

To some extent the onus now falls on policy makers, administrators and instructors to act upon the information presented by STEBI researchers to affect change within science education. There is now a plethora of evidence indicating that transmissive, content-heavy science courses should no longer serve as the cornerstone of pre-service and in-service science education programs. Student centred practices such as cooperative learning (Palmer 2006), inquiry learning (Swards and Dooley 2010), alternative conception targeting (Bautista 2011) and problem based learning (Eshach 2003) have been shown to improve participants’ science teaching efficacy beliefs across varied time periods and national contexts. Innovative practices will be vital to ensuring teachers are able to foster the scientific literacy of their students as they function in an intermediary role of connecting the general populace with the scientific community. There also appears to be opportunities for universities and colleges to play an expanded role in science education at more fundamental levels. Community and school partnerships (Nadelson et al. 2012; Urquhart and Bober 2006) can be viable means of expanding the influence of student-centred university programs and addressing issues that may arise as teachers transition from undergraduate study into the teaching profession. Online modes
of communication promise to make meaningful partnerships between schools and universities more accessible than at any point in history.

As a fledgling researcher and science education academic, it has been both a privilege and an enlightening experience to critique, summarise and organise the research of the STEBI scholars that have preceded me over the past 25-year years. Since the initial publication of the STEBI instruments (Enochs and Riggs 1990; Riggs and Enochs 1990) the body of literature has expanded to over 240 articles and dissertations (and still rapidly increasing); with contributions from over 20 nations making this area of science education research a truly global enterprise. I wholeheartedly believe that our predecessors have laid the foundation necessary to address many of the widespread and evolving challenges to science education that hinder the development of global scientific literacy levels. Education is the omnipresent, yet seldom considered, factor that underpins many of the political, environmental, economic and social challenges at the forefront of our attention in modern times. Therefore, the value of the contributions of teachers, academics, policy makers, educational designers, politicians and other interested parties to science education cannot be overstated. It is my sincerest hope that you, the reader, can extract some value from this Springer Brief. Whether you enter a new branch of science education research, review another body of science education literature, implement broader reforms to your science education practices or, simply, make a minor tweak to the science education in your context, this STEBI review will have achieved the desired purpose. I will be satisfied even if just one doctoral student manages to save some time and/or potential insomnia. I look forward to witnessing the progress of the STEBI literature and making some contributions of my own over the next 25 years.

References


Connective Statement One

The first publication “The Science Teaching Efficacy Belief Instruments (STEBI A and B): A comprehensive review of methods and findings from 25 years of science education research” served the key purpose of an extended review of Science Teaching Efficacy literature for this thesis. Research utilising the Science Teaching Efficacy Belief Instruments (A and B) has increased rapidly, both in terms of national contexts and publication rate, since the seminal publications in 1990. A review of the STEBI-A/B literature was needed to ensure consistency and clarity for contemporary science education researchers. A systematic review of literature yielded 107 STEBI-A (see appendix 5, p.393) research items and 140 STEBI-B (see appendix 4, p.387) research items. Varied research contexts and purposes are reflected in the spectrum of research designs within which the STEBI instruments have been used; qualitative, cross sectional, quasi-experimental, experimental and longitudinal science education research projects have featured the STEBI in the collection of data. Such expansive influence has consolidated the position of the STEBI as key instrument within science education research over the past quarter of a century. The STEBI instruments have afforded a unique opportunity for the impact of science interventions, delivered to preservice and inservice teachers, to be assessed in relation to participants’ science teaching efficacy beliefs and subsequently compared across contexts. Pedagogical approaches such as curriculum development, inquiry learning, embedded practical experience and cooperative learning have all been linked extensively to the improvement of the science teaching efficacy of pre-service and inservice teachers. As a whole, the STEBI literature clearly suggests that
science educators should forego traditional teacher-centred, transmissive course designs in favour of more active, student-centred design choices.

The combined work of prior researchers in this field of science education has provided a clear overview of the different innovative practices which have been used to improve the science teaching efficacy beliefs of preservice and inservice teachers. Such an overview will serve as a point of reference to contextualise the research presented within this thesis.

Aside from providing global contextualisation for the research to be presented, the analytic framework shown in the previous publication highlighted the unknown relationship between innovative practices and participants’ improved STEB scores. That is to say, the STEBI literature has given a clear indication of what approaches to tertiary science education may work but there remains a need for rich description of replicable science education courses to show how such approaches can be consolidated into effective science education experiences for preservice and inservice teachers.

The publications to follow within this doctoral dissertation will contribute to the STEBI-A and STEBI-B bodies of literature that have been summarised and critiqued in the first publication. The next publication entitled “The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model” (McKinnon, Danaia & Deehan, 2016) will lay the foundation for the rest of the evaluative research by describing two complementary, innovative primary science education courses which draw on many of the practices explored in the first publication.

To address the “question mark” cited within the analytic framework, the following publication will present two extended vignettes articulating the
development and design of the aforementioned science education courses. An emergent Interactive Education Design Model (IEDM) is presented to both frame the reflective, research-based course design process and present a model for course design for researchers and practitioners across varied educational contexts. Qualitative (interview and subject evaluation comments) and quantitative (Astronomy Diagnostic Tests and STEBI-B surveys) data are presented for simultaneous description and evaluation of the SC108 and SC308 courses. SC108 participants were initially shocked by their alternative scientific conceptions revealed at the beginning of the semester. As they engaged in a series of high stakes assessments and inquiry-based microteaching experiences, preservice teachers addressed their alternative conceptions and reported improving science teaching efficacy beliefs. The preservice teachers continued to develop their pedagogical content knowledge and STEBs through the professional project-based learning scenario underpinning the SC308 course.
Publication Two

The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model

Publication two has been submitted to the Journal of Studies in Science Education (see appendix 7, p.398). Language and formatting have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Manuscript Drafting
- Manuscript Editing
The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model

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Biographical notes
David McKinnon has a profound interest in science education at all levels and especially involving astronomy, public outreach and teacher professional learning. David has been recognised nationally for his outstanding contributions to learning and teaching in science education with an Australian Learning and Teaching Council (ALTC) Teaching Excellence Award. He established and ran the Charles Sturt University Remote Telescope Project in 2000 and which delivered access to teachers and students around the globe until his departure in July 2014. He has been involved with the Las Cumbres Observatory global telescope network and its predecessor Faulkes Telescopes UK since 2003. He has undertaken extensive research into the impact of using remote and robotic telescopes on students and teachers. He was Professor of Education at Edith Cowan University and Director of the Institute for Education Research at Joondalup in Western Australia until 2016 where he now continues as an Adjunct Professor and undertaking research in the domain.

Lena Danaia is an academic within the School of Teacher Education at Charles Sturt University. She specialises in the science curriculum area. Lena previously worked as a teacher in both Australia and in the United Kingdom. Lena’s research in science education spans primary, secondary and tertiary contexts and has involved her working on a number of projects with a range of stakeholders. Lena’s PhD, awarded in 2008, focussed on students’ perceptions of, and performance in, secondary school science both before and after their involvement in a project that fostered investigative, inquiry-based
approaches in science teaching and learning and which provided students and teachers with the opportunity to control a telescope in real-time over the Internet. Lena has been recognised nationally for her outstanding contributions to learning and teaching in science with an Australian Learning and Teaching Council (ALTC) Teaching Excellence Award.

James Deehan graduated with a first class Honours degree from the Bachelor of Education (Primary) course in 2012. Since graduating James has worked casually in primary schools in the Bathurst region, with particular foci on science education, gifted and talented education and small school education. The subject of James’ Honours thesis was how the second science subject design influenced the science teaching efficacy beliefs of a cohort of preservice primary teachers. In 2013 James was offered an Australian Postgraduate award to complete a PhD at CSU Bathurst. In his PhD research, James aims to determine how the science subjects offered at CSU influence the science teaching efficacy beliefs and science teaching practices of early career primary teachers.
The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model

Abstract

Over the past 20 years there have been numerous calls for extensive educational reforms to preservice teacher education in the sciences. Recommendations for science teacher education programs to integrate curriculum, instruction and assessment are at the forefront of such reforms. In this paper, we describe our scholarly action–research approach to the teaching of science and science–method subjects to preservice primary school teachers. We present an interactive educational design model that incorporates Pedagogical Content Knowledge as an integrative mediating framework and which drives students’ interactions with the elements of the design model. We illustrate the approaches that we adopt through two extended vignettes supplemented by qualitative data, and present, in brief, 10–years of quantitative data that show significant increases in preservice teachers’ competence and confidence. Together, the qualitative and quantitative data suggest a newly developed sense of enthusiasm for science and an understanding of the role that it can play in the primary school curriculum. The data provide strong evidence that the approaches being called for in some of the reforms, such as Bybee (2014), actually work.

Keywords: primary preservice teacher science education; teacher education; teacher learning; college science teaching; pedagogical content knowledge; educational design model; science teaching efficacy belief
Introduction

Engaging primary school students in science requires competent and confident teachers capable of implementing engaging pedagogies (Appleton, 2003; Bybee, 2014; Tytler, Osborne, Williams, Tytler & Cripps–Clark, 2008), but many perceive themselves to be neither (Appleton, 2003; Bellocchi, Ritchie, Tobin, King, Sandhu & Henderson, 2014). Effective preservice primary teacher education, therefore, is one important way to build both of these attributes in our future primary teachers. Attempts to redress the issue of competence in many preservice teacher education subjects in Australia involve the science content being taught by Science Faculty in isolation from the pedagogies or instructional methods that they will require to teach it. That is to say, the science is taught by those who lack the pedagogical insights of what to do in the primary school classroom. Education Faculty, in the science methods subjects, typically focus on how to teach specific and different science topics each week in an attempt to cover the broad spectrum of the curriculum’s demands and to provide experiences for the pre–service teacher to employ a range of pedagogical approaches that can be used to teach the science content. Bybee (2014) criticizes this separated approach not the least because the audience do not have any specialised training in science nor indeed have they had much in their brief exposure to the broad science content of the primary school curriculum. They thus lack much of the science content knowledge that they will be expected to teach (Appleton, 2007; Goodrum & Rennie, 2007; Tytler, 2007). The consequence is that Australian primary-school teachers do not feel themselves to be competent and thus they lack confidence when confronted by the demands of the science curriculum that they have to teach. One result is that science
education in the primary school is often avoided or ignored, even although it is mandated (Angus, 2004). Indeed, the 2015 TIMMS data reports that the average amount of time spent doing science in the primary school is 57 minutes (Thomson, Wernert, O’Grady & Rodrigues, 2016). Overall, the performance of Australia’s Year 4 students is flat-lining while the performance of students in other countries is improving (Thomson et al., 2016). Teachers are key to improving this situation.

Bybee (2014) highlights the need for an integrated approach to curriculum, instruction and assessment in preservice science education subjects. He notes that such an approach would be “very different” to the disjointed or fragmented approach of how science is currently and typically covered by teacher education institutions. The more traditional approaches employed by many teacher education institutions around the world tend to employ a fragmented approach to the science content, one which is much criticised by Bybee (2014). That is to say, a typical approach focuses on pedagogical techniques on how to teach particular concepts with little developmental continuity in the science content. For example, this week is ‘little beasties’, next week is ‘the weather’ followed by ‘push and pull’ and perhaps the week after ‘the Earth and Moon’ (Bybee 2014) and so on.

In contrast, Bybee (2014) claims that the different and integrated approach would involve deep, intense experiences that combine disciplinary knowledge with scientific practices through students undertaking investigations. In the Australian context, Lawrance and Palmer (2003) and Palmer (2007) identified a number of innovations in primary-school teacher education at both the program and the subject level in a sample of tertiary institutions some of which foreshadowed Bybee’s (2014) call for the
integrated approach. Innovations included: developing positive attitudes by emphasizing the use of motivating “hands-on” activities and the use of real-life examples; the integration of science with mathematics; the use of interdisciplinary approaches that integrate science and mathematics with other curriculum areas; the use of problem-based learning to give students some control; the integration of content and pedagogy through the use of themes; the use of constructivist approaches to investigate real-life problems to build positive attitudes; and, linking theory with practice through incorporating visits to schools to practise the science pedagogies about which they have been learning. Lawrance and Palmer (2003) noted, however, that the institutions included in their study typically displayed only one of these innovations, which was often instigated and maintained by only one or two motivated staff members. Consequently, educational–design development and succession planning were problematic.

Many key researchers and writers in the field also highlight the importance of Pedagogical Content Knowledge (PCK) in preservice teacher education subjects (e.g., Appleton, 2003, 2007; Hofstein, Eilks & Bybee, 2010; Lawrance & Palmer, 2003; Tytler, 2007). This construct appears to be missing from the innovations listed above. It could be argued that PCK is the key construct that melds many of these innovations within a constructivist approach to the learning and teaching of science for preservice primary-school teachers. This melding may provide important synergies to render science–methods subjects accessible, engaging and understandable to produce primary-school teachers who are more motivated to teach science. Research indicates that PCK can be developed through teacher education

Moreover, we would argue that there is a pressing need for the inclusion of detailed and replicable descriptions of science interventions in the science education research literature to serve the dual purposes of facilitating replication studies in alternate contexts and the goal of effecting lasting, positive changes to tertiary science education practices globally. Deehan (2016) articulated the need for more detailed descriptions of science interventions when he highlighted the unknown relationship between the use of innovative practices reported in the literature (Lawrance & Palmer, 2003) and student outcomes in a review of the science teaching efficacy belief literature. It appears that we know what works but not how successful, innovative pedagogical approaches can be implemented in different educational contexts. Indeed, concepts such as cooperative learning, constructivism and inquiry learning are often presented in the theoretical domain with limited discussion of practical pedagogies (e.g., Abrams, Southerland & Evans, 2008; Settlage, 2007). It could be argued further that results-driven-publication processes place unintentional limits on the intervention descriptions offered by researchers (Cantrell, 2003; Utley, Bryant & Moseley, 2005). However, in recent years researchers have attempted to articulate replicable science interventions in academic publications (Northcutt & Schwartz, 2013). If successful innovative interventions are to become mainstream inclusions for the preparation of preservice teachers in science education, deep descriptions of the interventions and the accompanying educational design processes as well as
their effects need to be encouraged and presented within the research literature.

The purpose of this paper is thus fourfold. First, an interactive educational design model (IEDM) is presented that emerged from our scholarly interrogation of the message systems of education, curriculum, pedagogy and evaluation (Bernstein, 1971). Second, the IEDM–in–action is illustrated using two extended vignettes of the science subjects to illustrate the interactions amongst the design elements and to demonstrate the mediating role played by PCK. Qualitative data collected from students as they undertook their journey in these science subjects is integrated within the vignettes to illustrate the effect of the design. The model contains many of the innovations outlined by Lawrance and Palmer (2003). Importantly, it incorporates PCK as an integrative mediating framework that drives all students’ interactions with the design elements. After 2008, the IEDM was employed in two science subjects in a Bachelor of Education degree at an Australian university for primary-school preservice teachers all of whom were participants in the participatory action research conducted and for which ethical clearance was granted (Protocol Number 2006/122).

Third, quantitative data collected over a ten–year period are presented to illustrate the impact of the implementation of the IEDM in terms of the Appleton (2003) criteria of competence and confidence. Two sources of quantitative data are presented: a shorter version of the Astronomy Diagnostic Test (CARE, 2002, 2004) comprising 15 items that are mapped to the content requirements of one component of the primary-school Australian Science Curriculum and which is administered on both pre– and post-subject occasions separated by an interval of 14 weeks; and, a slightly modified form
Fourth, the discussion examines the implications for the future design of tertiary primary-school teacher education preparation programs in science education in light of the changes called for by Bybee (2014) and Tytler (2007) within the new Australian Science Curriculum. The presentation of an IEDM, and two extended vignettes, will serve as a replicable model of student-centered tertiary science education. It thus helps to bridge the divide between preservice primary-school teacher education research and mainstream science teaching practices in tertiary institutions.

Context

In 2004, we were charged with delivering two science subjects at very short notice. With no time to make changes, we delivered what had been done over a number of years. In this mode of delivery, it rapidly became clear to us that our students were afraid of science, were not engaged by it, and chose to talk about their social lives rather than engage with the science topics they encountered in class. Moreover, less than 10% of them read the assigned subject materials and their attempts at the assessment items left much to be desired. A major evaluation at the end of the semester of what had been achieved (i.e., little), led us to formulate a participatory action-research project that we implemented in 2005. In moving from the old subject design to the new one, we asked two key questions: “What characteristics should our students possess on finishing each of these subjects?” and “How would we know?” In defining these characteristics, we arrived at a new assessment frame that we then backward mapped to define the learning experiences students should encounter.
We were also motivated to generate subjects that drew on a number of approaches that research had demonstrated led to engagement and high performance. These included cooperative learning (e.g., Johnson, 1994), problem–based learning (e.g., Duch, Groh & Allen, 2001) and, mastery learning (e.g., Bloom, 1971) all of which were designed to interact in ways that developed in our students a sense of *competence* with science and who were sufficiently *confident* to teach it. We also decided that “less was more” in the sense that we restricted the science content to astronomy rather than cover a new topic each week, which had been the previous modality. In the second semester, 2005, we assumed control of the second science methods subject that was designed to extend both students’ pedagogical repertoire and their knowledge of scientific content.

Our university had adopted the Bologna Model for Higher Education (Van Damme, 2001) to inform the workload that was required of students. Delivery of our two subjects was face-to-face in a one hour mass–lecture format followed by a two–hour practical class in a room that emulated what a primary-school classroom is like. That is to say, it had moveable tables, a wet area with three sinks and two small storage rooms. We refer to these two–hour classes as a “practical class”, which had a maximum of 24 students divided into six cooperative learning groups. We built a workload that would take a successful student eight to nine hours each week to complete at home or in the library. This requirement, in conjunction with the face-to-face classes met the requirements of the Bologna Model of 144-166 hours of study over the 14-week semester.

A small internal teaching grant provided six networked computers in the practical classroom: one for each table group. Students were also
encouraged to bring their laptop computers to the practical classes, which also had access to the university network through a WiFi access station installed in the room. Such infrastructure allowed students to access the Internet and subject materials as required. All subject materials were supplied in a hyperlinked digital format at the start of the semester through the Learning Management System and through USB drives. Our intention was that the computers would be used as “learning tools” by the students.

Interrogation of the impact of these two redesigned subjects with the two different cohorts of students in 2005 led us to modify both for the 2006 offering. One major modification was to the mastery learning and assessment frames. This modification involved students being awarded the mark that they achieved on the first occasion of their submission of an assignment. If they had not demonstrated mastery over all components, they could choose to re-submit, and could continue to do so, until mastery had been achieved in which case they became eligible for a passing grade in the subject. This overcame the tactic of some high achieving students continually re-submitting their attempts to get higher and higher marks even although they had achieved mastery.

In undertaking the learning experiences that had been mapped to the assignments, it was clear that many experienced difficulty in understanding the science concepts and of understanding why the subject format had been changed so dramatically. Consequently, in 2006 we implemented an approach that sought feedback after every class. This took the form of a one-minute paper that asked five questions: What worked for you? What could be improved? What did you learn? What do think you now need to learn? and,
Can you give five words to describe your feelings about what happened this week?

Initially, this formative feedback was collected on a hand-written paper template. Analysis of these was tedious and so we progressed to using an online survey form that enabled students to complete the questions before leaving the practical class. This allowed us to analyse rapidly their formative feedback and to discuss what some of it actually meant. At the start of the lecture during the following week, we presented our analyses and conclusions together with what we were going to do to address particular problems/situations that week. In some cases, we set small cooperative learning tasks to address issues that students could tease out amongst themselves (e.g., why we were now doing science this way).

After the very powerful gains in students’ content knowledge achieved in the first year of the project, we were somewhat surprised and disappointed with the much lower gains in 2006. Consequently, in 2007 we required that students directly deal with all of their alternative scientific conceptions during their “micro–teaching” experiences planned for each week throughout the first subject. These are more fully described in the first vignette below. In addition, further interrogation of the 2006 outcomes led us to introduce, in 2007, the Science Teaching Efficacy Belief Instrument–B and to use the Personal Science Teaching Efficacy (PSTE) scale as a de facto measure of students’ confidence to teach science. In a different sense, the Science Teaching Outcome Efficacy (STOE) scale became a de facto measure of how they perceived the subject design changes that we had introduced impacted on themselves.
In early 2008, we struggled to understand what seemed to be motivating our students to become curious, to appreciate science, to see its power as an integrative frame for other curriculum areas, and leaving them wanting to design and implement engaging learning experiences for their own students when they arrived in schools as teachers. In this scholarly approach, described by Shavelson, Young, Ayala, Brandon, Furtak and Ruiz–Primo (2008), we pursued an almost constant interrogation of our practice. As we investigated the apparent interactions amongst the various components of the designs of the two subjects, an explanatory model emerged.

The model that we describe below represents a clearly defined method of developing preservice teachers’ science PCK in ways that are applicable to science teaching practice in the primary school. Continued interrogation of the model in subsequent years has revealed its stability and power. Our analyses have allowed us to anticipate the conceptual difficulties that students are likely to encounter as well as their evolving concerns as the semester unfolds and to address these to help allay their fears.

**The Interactive Educational Design Model**

The Interactive Educational Design Model (IEDM) that emerged is presented in Figure 1. It combines a number of well–researched educational-design frameworks in pedagogy and assessment. Elucidation of the model below illustrates the ways in which the authors now intentionally craft a profound personal learning journey for the primary-school teacher education students that requires them to extract, from their in-class educational experiences, the knowledge and skills required to create inspiring science classrooms.
The Interactive Educational Design Model (PCK= Pedagogical Content Knowledge)

The model comprises three key design elements located at the vertices of the model: Content; the Assessment/Evaluation/Feedback system; and, Significant Others. These elements are described first before considering their interactions. The IEDM embeds students within the construct of Pedagogical Content Knowledge (PCK) and its development as the mediating domain that deeply influences all interactions between students and the design elements. The location of students at the centre of the IEDM signifies the student–centered nature of the approach.

The Content
This design element of the IEDM facilitates students’ access to all of the content and the resources developed for the subjects. The materials are
provided at the commencement of the semester in a digital format both via USB and through the Learning Management System used by our university. The materials are organised into multiple folders with access facilitated by extensive hyperlinking from within the collection of PowerPoint lectures and Word based tutorial documents as well as to other applications such as spreadsheets, movies and software.

Delivering the content in this way is designed to achieve two major aims. First, students have access to all of the materials from the outset of the semester of study. Second, it allows the teaching teams across multiple campuses to achieve a high degree of implementation integrity. The latter issue is of importance given that multiple instructors are employed across our multi-campus university to deliver the subjects and to evaluate the assignment products in a consistent way. Students’ reactions to this level of organisation and distribution is extracted from data collected in the Evaluation and Feedback System. Many examples are presented within the two vignettes.

**The Assessment/Evaluation/Feedback System**

These three components constitute one design element in the model and are presented separately in this section. Nonetheless, they are constructed to interact in powerful and supportive ways. The vignettes that follow the description of the IEDM illustrate the interactions amongst them.

**Assessment**

The assessment domain is constructed by asking ourselves the question “What would be the characteristics of the student who has *successfully* completed this subject?” This then begs a further question of “How would we *know* that a student possesses these characteristics or has acquired them
during the subject?” The assessment domain is thus defined by the process of Backward Mapping (Shavelson et al., 2008) with the early assignments each addressing a particular component of PCK. In defining these student characteristics, the assignments are developed in ways that allow instructors to be confident the students have acquired the knowledge, the skills and the attitudes and values, which the instructors wish them to acquire.

To help the students achieve the outcomes, assessment rubrics contain clearly defined performance criteria and are supplied to the students within the digital materials. The standards within the rubrics are specified in such a way that the student is in absolutely no doubt of why they were assessed at a particular performance level. Words like Satisfactory, Good, Very Good and Excellent in relation to any component of a report or essay are an anathema to students who cannot decode these words in any meaningful way. Nor are they useful to instructors who are left with only their own qualitative experience and judgement for making any call on the differences between Good and Very Good or Excellent.

Consequently, the authors employ a criterion–referenced assessment framework with a set of clearly specified performance outcomes for each of the components of each assignment. Specific criteria, or standards, for each component also present clear structural guides for student performance from Pass through High Distinction. These criteria have the added benefit of increasing the reliability of assessment marking for the instructors. The joint effect of these analytic rubrics is that students understand what is expected of them and the standards at which they can choose to deliver their attempts at the assignment in order to be deemed eligible to pass the subject. The construct of PCK progressively and cumulatively mediates students’
interactions with the sequence of assignment items, their engagement with the curriculum content, focuses their attention on each of the sub–components of PCK in a developmental way and, assists them to understand the role that PCK will play in their design and delivery of science learning experiences for their future students.

**Feedback**

Feedback occurs at a number of levels on multiple occasions during a semester: from students to the instructors, from instructors to the student, and from student to fellow student. Students provide formative feedback to the instructors each week. They, in turn, provide both formative and summative feedback to the students on a weekly basis and on the occasions when assignments have been tendered for assessment. Students provide feedback to each other as they develop their cooperative learning products and when micro–teaching events happen (Cochran, King & DeRuiter, 1991; Niess, 2005). Summative feedback in relation to the delivery of the subject is provided by the students to the instructors at the completion of the semester of study both through the formal University online system and through an extended paper–based questionnaire. At the completion of the semester, the summative feedback provided by students coupled with the formative feedback collected each week are interrogated by the instructors in a scholarly way. Interventions can thus be implemented in at least two ways: “on-the-fly” each week to deal with any barriers to the students’ learning, or in a structural way to provide for more major changes to a subject during its next offering.

The use of “one–minute feedback papers” obtained at the end of each class provides solid evidence of the way in which the instructors are concerned that no student is left behind. This formative feedback mechanism
was introduced to elicit information from students when it became clear that, despite our early efforts, some students could not disentangle the “message” from their “feelings” about what was happening. Consideration of this form of feedback thus allows the instructors to undertake deeper reflections about their teaching and to develop interventions that are implemented in the following lecture where students are presented with an analysis of the feedback received and the actions that will be undertaken that week. Analysis also allows the instructors to identify learning barriers and conceptual problems that can be dealt with expeditiously before they become a problem.

The support mechanisms for students’ development as cooperative learners led to the creation and implementation of a *Cooperative Learning Evaluation Feedback* instrument to identify emerging difficulties in any interactions within their groups. Once problems are identified, the instructors act as “counsellors” to address the issues within a group but take care not to single out individuals. Members of a problematic group are directed to relevant literature supplied to them in the digital materials on how to function more effectively, for example, a short paper on *Assertive Communication* and how to implement it (Hoffman, 1978). Discussion then follows that is led by the instructor on how they might deal with *their* problem. The group’s progress is monitored together with effective forms of communication being modelled and positive feedback provided as skills are developed and demonstrated. This support is important because, as teachers, they will be required to collaborate with their peers as well as to provide assistance for their future students to do the same. When our students come to conduct experiments and teach the content to each other, a *Structural Reflection and Feedback* instrument helps focus their attention on what worked and what did
not. In addition, it provides a formal assessable mechanism for them to provide feedback to the peer who had attempted to teach them.

Subject Evaluation
Instructors at our university are required to evaluate each subject at the end of each teaching semester. This process is achieved through asking students to respond to a number of core (11) and optional (29) items provided by a central body within the university charged with evaluating the delivery of all subjects. The core items are common across all subjects within the university. Instructors can choose additional optional statements from an item bank because of their relevance to aspects of a particular subject. All items require a response on a seven–point Likert Scale from Very Strongly Disagree through Very Strongly Agree. In addition, students may add written comments if they feel so moved. The average response rate for these anonymous surveys at our university is typically around 30%. However, in these two subjects it is always greater than 90%. Typical extracts from some of these summative subject evaluations are provided in the two extended vignettes below.

Significant Others
The students rapidly realise that their peers within their group, within their practical class and, more broadly, across their cohort constitute one aspect of the design element of Significant Others. The realisation is rapid: indeed it happens within their first week of their first semester of study. They understand that they are dependent on the cooperative learning products that others within their group, their practical class and their cohort generate and all of which contribute to the production of the assessment items in part, or as a whole. For example, in writing an academic essay on alternative conceptions, they understand that everyone in the year group contributes to
the literature base to which they are exposed in a jigsaw fashion (Slavin, 1996) where the extensive reading list has been divided amongst the entire cohort. Thus, they understand that they will cooperate with others to generate their assignment responses for assessment.

The instructors also play a role as significant others. They model for the students within their own particular practical class the behaviors that are required of them when they become teachers. They model how to: interrogate the scientific content; evaluate and comment on the appropriateness of instructional strategies to teach particular content; assess the learning outcomes to be achieved; mediate when difficulties arise in the social dimension; and, set realistic goals.

Finally, Significant Others also include those whom the students will, perhaps, never meet personally. These are the science education researchers to whose work they have been exposed, and the scientists whose work they will encounter and include in their classes when they become teachers.

The five key elements of cooperative learning drive students’ understanding of the extent to which they are dependent on the work of significant others in their journeys to become teachers. The five elements are: face–to–face promotive interaction (i.e., in-person interactions contributing to a specific goal); positive interdependence (i.e., the knowledge that the members need each other to achieve a specific goal); individual accountability (i.e., each member is responsible for making a contribution to a specific goal); interpersonal and collaborative skills (i.e., communication skills such as conflict management, leadership and decision making); and,
reflection/group processing of all interactions (i.e., reflecting on group actions for the sake of improved performance) (Johnson, Johnson & Smith 1998).

*The Interdependence amongst the Design Elements*

The longer and lighter double–headed arrows in Figure 1 signify both the interdependency amongst the design elements and the dynamic and mutually supportive nature of their interaction. For example, when preparing an assignment, students are required to assimilate certain *Content* delivered in the digital materials and to interact with *Significant Others* in the form of their peers and instructors. Interaction amongst the design elements thus creates the environment for students to learn both the scientific and educational content, to appropriate a variety of instructional strategies, and to produce quality assessment responses throughout the subject.

*The Mediating Role of PCK*

We have operationalized the construct of PCK to comprise the layered and embedded components of alternative conceptions, context and beliefs about purpose, the Science and Technology Syllabus, cooperative learning and instructional strategies, and the current body of scientific knowledge (Cochran, DeRuiter & King 1991; Grossman 1990; Shulman 1986). These mediate all interactions that the students are required to have with the design elements. These components are instrumental in developing the more complex construct of PCK as these preservice teachers begin to make decisions *within* each of these components and to move *amongst* them in response to the complex and unfolding learning context.

Each of these components of PCK is bounded by broken lines to indicate that they are not fixed. That is to say, knowledge of these components of PCK grows with time, with critical reflection, and with their expanding
personal experiences in science education. They come to understand that they
do not stand in isolation from one another. These components of PCK provide
them not only with a framework within which to engage with the contents of
the two subjects but also with a context to access a wider range of ideas and
the significant others with whom to explore and discuss effective science
learning and teaching.

Thus, these components of PCK mediate all students’ interactions in
varying ways with each of the three design elements. The short black double–
headed arrows thus serve to indicate that the students interact with each of the
three design elements in ways that are mediated by their interactions with the
components of PCK. Most importantly, locating the students at the centre of
the IEDM serves to indicate that the locus of control rests with them, that is,
when they are studying the subject materials, communicating with their peers,
instructors or others, or preparing assignment responses.
The Two Extended Vignettes

The vignettes presented here illustrate how the design elements of the model come together to form an integrated approach to the education of preservice primary-school teachers whose role will include the teaching of science. They further illustrate how cooperative learning and backward mapping of the assessment tasks are instantiated within the learning experiences. The context for their journey in Subject 1 is a problem–based learning environment that is constructed to address their limited scientific knowledge, and the many alternative conceptions they hold. Subject 2 progresses the educational outcomes developed in the first subject. These are enacted within an authentic project–based learning environment to extend students’ mastery and professional orientation in readiness for their transition to becoming reflective practitioners and effective teachers of science in primary schools.

The First Subject (SC108)

Subject 1 is one of four that students experience in their first semester of a four–year Bachelor of Education (Primary) degree leading to employment as a primary-school teacher. This subject is largely a science content one but taught in a markedly different way to those criticized by Bybee (2014). We integrate the learning of the content with the pedagogies students will employ as teachers of science using elements of Pedagogical Content Knowledge as a developmental frame within a problem-based learning (PBL) environment.

The authors create the PBL environment at the outset of Subject 1 by administering a modified version of the Astronomy Diagnostic Test (ADT) (CAER 1999) to students at the first whole–group lecture of the subject. The 15 items are mapped to the outcomes of the primary-school science curriculum and have been modified by the authors for use in the southern
hemisphere. That is to say, students in years 3–6 are expected to know the material contained within this version of the ADT. In addition, our students are invited to present the reasoning for their answers. This allows us to analyse the structure of their alternative conceptions. The ADT thus serves several purposes. It creates the preconditions for the PBL environment where their learning is the issue to be addressed. Their results shift their perception that it “… is only primary science. I have been to high school and so I will know more than them” (GN). More importantly, in illustrating what they do not know, it defines what they will need to learn in the classes that follow (Hickey, Taasoobshirazi & Cross 2012).

In considering the issue of confidence to teach science, the work of Bandura (1977) has much to offer where the construct of “self-efficacy” is defined as a general anticipation about future events (the outcome domain) based on previous personal life experiences (the personal domain). Enochs and Riggs (1990) developed an instrument that attempts to measure science teaching efficacy in these two domains. One, Personal Science Teaching Efficacy (PSTE) is “a teacher’s confidence in his or her own teaching abilities” and the second is the Science Teaching Outcome Expectancy (STOE) as “a teacher’s belief that student learning can be influenced by effective teaching” (Ramey-Gassert & Enochs 1990). The instrument was later modified slightly for pre-service teachers called the Science Teaching Efficacy Belief Instrument–B (Riggs & Enochs, 1990). The students are asked to complete the Science Teaching Efficacy Belief Instrument–B (STEBI–B).

In self–marking their attempt at the ADT in the following practical class, our students are able to identify their knowledge gaps in the astronomy
component of the syllabus and gives them almost immediate feedback concerning the many alternative conceptions they hold (Hickey, Taasoobshirazi & Cross, 2012), for example, that it is the Earth’s shadow that causes the phases of the Moon, or the Earth’s distance from the Sun that causes the seasons. Their marks typically range from zero to a maximum of five out of 15 possible marks with a mean of around 1.5 each year.

We then confront them with the Science Syllabus outcomes for years 3–6 against which the 15 items are mapped. The impact on the emotional climate of the class is both immediate and profoundly negative (Bellocchi et al., 2014). They are asked to record their personal reactions in a Word document on their personal, or tablet, computers. They use words such as “horrified, shocked and stupid” in reporting their feelings. We then ask them to form groups of four and to share both these reactions and their score with their new table–group peers. We also ask them to record the varying reactions expressed by their peers. By this stage they have almost completed the homework for the first low–stakes assignment that requires them to write a short reflective essay about what they know, what they will need to know if they are to become primary-school teachers, and to map their lack of knowledge against the Science Syllabus requirements in this content area. In this process, they begin to navigate the Science Syllabus document. They also discuss their feelings about both their own result and those of their group before presenting a “conclusion”.

In considering these results, they clearly understand that there is a problem. They articulate it on both the first formative feedback occasion using the one–minute–feedback instrument and in their first assignment responses: “[T]o teach science, knowledge is needed… more knowledge than
what I have” (Anon); “If I don’t know the content then how will I know how to teach it?” (LD); and, “[T]he test helped me to understand just how much I need to learn” (Anon).

We also analyse how they feel from the five stream–of–consciousness words used by them in the one–minute–feedback papers. Words such as “angry, anxious, confronting, daunting, embarrassed, shocking, and stupid” are used with high frequency. The anger that they express relates to the fact that they “don’t remember being taught this stuff at school” (many). Over 80% of these words can be classified as negative and reveal the extent to which they are shocked and stressed yet, at the same time, also influenced and motivated by the revelation that they know little. This is illustrated by further words interspersing the negative ones above that constitute around 10% to 15% of the total and which may be classified as positive: “eager to learn more, enjoyable, exciting, learning opportunity and motivating”. In a relatively brief period of time, the climate changes from a sense of personal failure, to an intermediate one of relief that each individual is not alone, to one involving anger yet balanced by a sense of personal motivation especially when the instructor emphasises that the problem is even more general than what they have just experienced (Bellocchi et al. 2014). The endemic nature of these alternative conceptions becomes apparent in their preparation for second assignment that begins immediately afterwards.

In this first class, we further develop the potential for increasing their motivation through exposing them to the extensive research literature on alternative conceptions possessed by students, teachers and preservice teachers. In this exercise, and consistent with collaborative learning principles, the task of reading and analysing the body of literature is too great
for any one individual to execute in the time available (18 days) to produce the second assignment. Thus, we employ a variety of cooperative learning strategies including jigsaw, roundtable, think–pair–share, and numbered–heads–together (Slavin, 1996), to demonstrate that alternative conceptions are widespread. In the process, they come to understand that their lack of knowledge is not unusual.

For homework, each student is required to read one supplied journal article dealing with the alternative conceptions of a particular population (teachers, preservice teachers, primary-school students) and to locate and read a second one on an associated topic. In order to scaffold their reading of the research papers, they respond to a set of six questions that focuses their attention to elicit relevant information pertinent to their second assignment. For homework, they summarise these responses to the two papers before meeting with a partner who has read and answered the same questions on two different papers covering the same population. This think–pair–share exercise requires the pair to come to the second class with a digital summary of their findings covering the four papers. Each group then employs a roundtable approach to understand each pair’s findings for each of the two populations covered within their group. A numbered–heads–together strategy follows allowing the members from the various groups to share their findings on the alternative conceptions possessed by the three populations: school students, preservice teachers and in–service teachers. On return to their own group, a form of roundtable that we have called “cascading roundtable” is employed to share what each individual has learned from the other groups. This form of roundtable is designed to elicit for discussion, without repetition, all of the information supplied by the various groups. In this process, we demonstrate
the value of the cooperative learning strategies being employed, their pedagogical value, and make this explicit for the students.

These processes provide the scaffolding necessary for them to understand a large body of literature that deals with the background reading necessary for the production of their second assignment: an academic essay on the non–scientific conceptions held by the three populations. Extracts from this second assignment demonstrate that this literature has a deep impact on their motivation. Many state that they will have to identify and address their own alternative conceptions first so that they will not teach these to their students, for example, “I am shocked by the information that teachers teach alternative conceptions” (LD). Moreover, they are highly motivated to do something about “their problem” as exemplified by the following extract from one essay.

I feel that this diagnostic test was both revealing and confronting. It is scary to think that after 13 years of schooling I still have no idea about something as simple as the relationship between the Earth, Sun and Moon. It is from this realisation that the motivation comes to create an exciting and memorable science experience for students in schools (EC).

These highly personal experiences provide a framework for the groups to construct a learning program that is submitted as a cooperative group assignment. The third assignment requires them to sequence the investigations that will address their alternative conceptions, map each of these against the syllabus outcomes, and identify who will be responsible for teaching each one to their small group. The activities they have to choose are to meet their collective content–knowledge deficits. The assignment gives them a real purpose for the learning of the astronomy content that is to follow where they will experiment with instructional strategies to teach each other.
This assignment drives their interactions with the mandatory science curriculum documents, and with the terminology therein, as they begin to grapple with sequencing their investigations in some sort of logical way with help from their instructors. The groups incorporate relevant projects into their learning program from the digital compendium of projects provided by the authors. From these projects, we have deliberately removed any hints on how to teach them so that they can experiment with various instructional strategies that engage both them and their peers and later, perhaps, after reflection, the students in their classes (e.g., explicit teaching, conceptual change, cooperative learning strategies, guided and open discovery, modelling, and interactive teaching).

In engaging with these investigations led by a peer, a beginning understanding emerges of the importance of this battery of instructional approaches to the effective teaching of science. This emerging grasp of the importance of the strategy was illustrated when one student said after experiencing the project on the cause of the seasons taught by one of his peers using explicit instruction “[B]ut I wouldn’t teach it this way” (MR). When asked why, he responded in ways that indicated his developing understanding of the issues by pointing out the need to break the task into “manageable chunks” over a series of lessons in order to “scaffold the learning of his future students” (MR).

In the six weeks during which the group members attempt to teach the projects to their peers, they employ a Jigsaw II strategy (Slavin 1996) and role cards. Each group member is required to lead the teaching of two of the projects. For any single investigation, one student assumes the role of teacher and thus has to become more expert on the topic in order to teach it to his/her
peers in the small group, while the others act as learners. These roles are swapped for other investigations. This entire process requires everyone to be involved working in their different roles during the class with students as teachers, students as learners, and the instructors as facilitators and mentors. These sessions are almost chaotic as each group undertakes different investigations according to their group’s needs and for the sequence they have adopted. Nonetheless, the classes are characterised by continuously high levels of task engagement.

Formative feedback illustrates the extent to which they are engaged: “I loved the Jigsaw activities – everyone brought something different” (NG); and, “We had a cooperative day where we got together and did it” (RO). As they engage with the content, there are many, many “Ah Ha” occasions when students come to understand such phenomena as the phases of the Moon or the seasons using conceptual change, modelling and guided discovery approaches. In the process, they construct highly personal mental models to explain various phenomena. For example, one student explained the apparent movement of the Sun in the sky during the course of the year based on the peeling of an orange. The sharing and explanation of this idiosyncratic mental model excited both the originator and her group as the abstract idea for the cause of the seasons was made concrete, viz., varying day length and varying angle of incidence of insolation due to the varying altitude of the Sun over the course of a year all caused by the axial tilt of the Earth and its orbit around our Sun.

Students’ reactions to the learning and teaching experiences that are occurring are formalised in the Structural Reflection and Feedback instrument we developed to focus their attention on the interactions of the components
of PCK (knowledge of: content; students’ prior conceptions; the syllabus; and, appropriate instructional strategies) they have been encountering so far within the subject. Feedback obtained during these sessions reveals students’ changed feelings (e.g., “active, beneficial, inspired, collaborative, engaging, enjoyable, informative, intense, interactive, interesting, powerful, productive, supportive, thought-provoking”). The balance of negative and positive words elicited in the one-minute feedback dramatically shifts to more than 90% positive and less than 10% negative by the end of Week 5, which is the second week of these teaching explorations. They now come to class with smiles on their faces rather than frowns. Our conversations with them reveal that they seem to “get it”.

Other, more informal, evidence bears this out. In the fourth year of the project, one student who had successfully completed both subjects wandered up to us in Week 4 and asked “How is this year’s mob progressing?” In response to a non-committal answer, the student offered “They seem to be getting it. I overheard some of them having coffee this morning talking about what you are doing with them” (RK). Of interest was the use of the preposition “with” and not “to” in this comment. Its use indicated to us the students thought of themselves as participants on a journey that was under their control and that the instructors were also participants in the learning and teaching that was occurring. This exemplified, for us, the desired outcomes of the participatory nature of the action research.

In short, although we had expected changes in students’ engagement, we were continually and pleasantly surprised by the extent to which task-orientated discussion happened within groups to the exclusion of other conversations, for example, their social lives. On one occasion, an important
University official visited one practical class and talked with the students as they undertook their investigations. He was intrigued by the extremely high level of engagement, the buzz of interaction and the disparate nature of activity at each group’s table. Impressed by the professional manner in which the investigations were being conducted, he asked us “Is it always like this?” an answer to which was given by one nearby student who interrupted with “Yes! Isn’t it exciting?” (NM).

A high–stakes written assignment tendered for assessment in the final week of the semester draws upon both their early work in the subject and on their teaching and learning experiences that involved their explorations of various instructional strategies, which scaffolded their development of PCK. A final high–stakes criterion–referenced test is based on the same set of the ADT questions and the answers to which have to be supported by scientific explanations represents the final assessment and demonstration of their understanding of the content. The performance criterion in the test is set at 70% with scientific explanations having to be proffered to support their answer.

Within the assessment domain, both formative and summative feedback are provided by the instructors. In one major sense, the formal assignment responses elicited, and the feedback provided, by the instructors serve both a formative and summative role (Buck, Trauth–Nare & Kaftan 2010). Instructors provide feedback to the students on their performance in assignments through the criterion–referenced rubrics within four days of the attempt being submitted. The feedback is formative in the sense that if the standards have not been reached, students are allowed one resubmission in order to “make the grade” and summative in the sense that their first attempt
is the mark that they “have to wear”. If a student who has not made the grade chooses to resubmit an acceptable attempt then they become eligible for a Passing Grade in the subject and marks are scaled in ways to reflect this achievement. This system means they try their best on their first submission but they know that if it is not good enough, they will have an opportunity to address the feedback provided and re-submit.

The students also provide the authors with both forms of feedback through their responses to the one–minute feedback papers and though the formal summative subject evaluation process mandated by the university. All forms of feedback are considered and used to modify the subject offering in the following year. Evolutionary changes are explained to each new cohort of students together with the reasons for these modifications so that they understand the dynamic, interactive and evolving nature of learning and teaching within the subject design.
The Second Subject (SC308)

The first subject serves as the platform upon which Subject 2 is built and which is undertaken in their fourth semester of study. Students have acquired significant skills in problem-based learning and cooperative learning strategies, and can apply these to address their lack of scientific content knowledge. Moreover, they understand the construct of PCK against which they can measure their development in terms of knowledge gains, facility with instructional strategies, knowledge of the curriculum, and of how students possess many explanations for their natural world, albeit not necessarily aligned with the scientific ones. These skills are developed further as they organise and jigsaw the many tasks described below, define the scope and sequence of content, identify appropriate activities, conduct various investigations to make sure that they work and, if not, to make adjustments, provide background knowledge/resources for any teacher who might use their unit, research the alternative conceptions that students might possess, define assessment procedures and feedback instruments and, communicate with each other effectively.

In Subject 2, we create a project-based learning context at the first meeting of a class where students assume the role of being “teachers” in a primary school and the instructors their newly appointed Executive. The “Principal” invites the “Staff” to get into their “teaching teams or Stage Levels” (Kindergarten, years 1 & 2, 3 & 4, 5 & 6) in the same way as the mandated curriculum is organised. The instructors present a scenario constructed from the national and international research literature together with reports on the state of science education in Australia and internationally. The new executive “have examined your previous science programs and
found them wanting” in terms of the curriculum requirements of the Science Syllabus and of the amount of time devoted to the subject. The scenario is presented in such a way that they understand that the other science classes also represent “schools” in the same district each of whom will develop Units of Work for the other content strands of the primary–school Science Syllabus and which gets drawn, at random, from a hat. Thus, collaboratively, the cohort will develop materials to cover all content areas.

In this context, the teaching teams brainstorm ideas and then apply a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) before reporting the outcomes to the other teams within their class. Each group apportions tasks to its members for completion within a set time–frame as they begin to develop their Units of Work on their particular content area drawn from the Science Syllabus that articulates from Kindergarten through Grade 6. That is to say, the four units of work developed within a particular practical class maintain a “continuum of learning” from Kindergarten to Grade 6 in a particular content strand: Life Sciences; Physical Sciences; Earth and Space Sciences; and, Built Environments (the science content of the Australian Science Curriculum). These Units of Work have to involve school students in “Working Scientifically” and “Working Technologically” (the skills) as they undertake their investigations and which will also be designed to influence positively their attitudes and values. More importantly, for any investigation that is to be included, the group has to conduct it and provide feedback for the writer. In this way, they develop further their knowledge of content, instructional strategies, alternative conceptions and the curriculum documents. All investigations are built around Bybee’s (1997) 5Es instructional model. Influenced and motivated by the process, many students
bring their laptops and tablets to supplement the six internet–connected computers in the classroom. Doing this also generates additional necessary information that is provided within their unit of work for those other teachers who may use it and who may not know it. They share their products using USB drives, email, Dropbox (or similar), closed Facebook groups that they set up and more informally through their many conversations and discussions within their own group, with their peers within their class, and also across the cohort.

At the staff meetings held at the start of a practical class each week, the instructors, acting as the Principal or Deputy, facilitate discussion as each group presents their latest outputs (the collaborative–learning products). At the end of the practical class each week, each group completes a meeting template, constructs an action plan and delegates tasks to be completed, individually or collectively, by the following week. These meeting minutes thus comprise a contract of work for the individuals within a group. The numerous roles are interchanged on a regular basis to ensure that all members acquire the skills of effective team management.

Halfway through the semester, their draft Units of Work are submitted for formative assessment with feedback provided within four days of submission. While acting on feedback, they also begin to make decisions about the activities that they will implement in local primary schools, which we visit in the second half of the semester to conduct a science day. The purpose of this in-school experience is to develop further their existing PCK together with its additional two components of knowledge and beliefs about purpose, and knowledge of context.
In testing parts of their unit with real students, they observe the impact that it has both on the students and on the teachers who are required to be present and from whom feedback is elicited. Groups employ various mechanisms to obtain this feedback that is then used to fine tune the electronic hyperlinked version of their unit of work presented as a set of digital hyperlinked and interconnected documents, which is submitted for summative assessment at the conclusion of the semester. The in–school experience visit has a major impact on them as illustrated by a common comment such as this one “I enjoyed the school visit as it added meaning to the learning which allowed me to engage in the subject” (SP). Indeed, when we investigated students’ written comments in 2011 with more frequent administration of the STEBI–B (eight occasions in 14 weeks), the impact of the in-school experience was reflected in a major increase in the PSTE score and which appears to be the largest increase in any one–week interval over the two subjects. In all other data sets that we collected from the Subject 2 cohorts, the STEBI–B was used only as a pre– and post-occasion instrument.

Treating our students as professionals in their field appears to be a major motivational factor that inspires them to act as teachers. Discussions center both on the impacts that their unit of work will have on students and on the coordination of various approaches, including curriculum integration, to improve the learning outcomes for school students. These high–level impact interactions are evidence of the professional way that they are being treated, their increasing confidence as teachers, and their developing expertise in programming and evaluation as illustrated by the following two pieces of feedback provided in the one–minute papers: “I feel the development of the unit was a rewarding and worthwhile exercise that allowed me to develop my
skills as a unit developer and teacher” (KD); “Overall, the subject layout was great – [It was] focussed on our development as science teachers” (KW). Summatively, many students comment positively on the scenario: “I liked the school/staff set up for classes. Thank you!!” (SN); “Make sure you keep the “school” format etc. – It worked very well” (ES). Moreover, they seem to understand the complementary nature of the two subjects as the following comment by a graduate illustrates:

   In SC1 [the first subject] our lecturers [instructors] were teaching us the teaching styles required to teach science. … In SC2 [the second subject] we were given the content and had to organise it into teaching experiences (GC).

An important additional motivational device introduced by us in the third year of the Project, 2008, involved us collating the many units of work and supplying them both to our students and to local schools on a CD–ROM. As the repository grew, the units of work were supplied on DVDs and more recently on 32 Gigabyte USB drives. Many students comment on the value of the collection:

   The unit development assignment was fantastic and was a very worthwhile exercise. Very valuable resource provided on CD–ROM” (CF).

Thus, our students exit this second subject with a full–school science teaching program covering all of the science content and skill components of the Primary School Science Syllabus with parts that have been trialled and evaluated. It also contributes to the professional learning of teachers in local schools, feedback from whom is extremely positive with many of them using the units of work with their classes.

   It is also worth noting that there has been no duplication of the contents of any Unit of Work over a 10–year period. Interpretations of what
can be done given the mandated outcomes are highly diverse. Thus, as the library of Units of Work grows, teachers can choose what is most appropriate for their class and make suitable adjustments to the digital materials to fit with their context. Evidence shows that the students are highly motivated, engaged and reflectively critical about their future roles with one student claiming:

This subject has been the most valuable core subject I have had so far – as we get useable units of work! There is something beneficial for us at the end of the subject and it makes the work worthwhile – not just to get a mark (MB).

We attribute these outcomes to the authentic project–based learning context into which they have been placed and the experiential learning in schools that has demonstrated to them that they can make a difference to the engagement and learning of students. Comments like the one above are not uncommon in the summative evaluations of the second subject provided by our students.

**Instruments and Interactions**

Of particular interest to us are the two constructs of *competence* and *confidence* (Appleton, 2003, 2007). We operationally define the construct of *competence to teach science* as the students’ performance on the postoccasion Astronomy Diagnostic Test in the first subject. The Personal Science Teaching Efficacy belief scale of the Science Teaching Efficacy Belief Instrument B (STEBI–B) is used to define the construct of *confidence to teach science* (Enochs & Riggs 1990). The other scale in the STEBI-B is the Science Teaching Outcome Efficacy (STOE) belief. This is perhaps an unknowable construct to the preservice teachers given that they have no context on which to base the results of teachers’ efforts other than their experience during their own schooling. Nonetheless, we were interested to
track changes in their STOE scale scores to investigate if our students were potentially generalising their instructors’ efforts within the educational design to the work of other teachers.

The Science Teaching Outcome Expectancy (STOE) belief scale has been reported in the literature to be somewhat problematic (Avery & Meyer 2012). Consequently, we modified the STEBI-B instrument in two ways. We employed an additional seven items from the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST) developed by Roberts and Henson (2000). Specifically, items 2, 7, 8, 13, 14, 15 and 16 were included in an attempt to bolster the construct of confidence to teach science. We subsequently computed a Confirmatory Factor Analysis on the resulting 30-items and employed a parsimonious approach through reliability analyses to reduce the number of items in both scales to eight. Reliability Analysis reveals that both scales possess high levels of internal consistency (0.91 and 0.79, respectively) on the post-occasion of testing while on the pre-occasion of testing, the STOE belief produced a much lower Cronbach’s alpha of 0.59. This latter finding is not entirely surprising given that our students had not experienced what efforts are required to generate the learning outcomes.

A Confirmatory Factor Analysis followed by Reliability Analyses were computed and, following the principle of parsimony, we chose to employ eight items in each of the two scales from the original 13 and 10 contained in the PSTE and STOE respectively reported by Enochs and Riggs (1990). We did this by simultaneously maximising the Cronbach’s alpha while retaining the power in Tukey’s Test of additivity as close as possible to 1.000 thus rendering the resulting scales additive. Each year, the items in the STOE scale yield a Cronbach’s alpha of between 0.65 and 0.70 on the
preoccasion, and between 0.79 and 0.82 on the postoccasion. The lower value of the STOE scale on the preoccasion is understandable given that our beginning students cannot truly know what a teacher has to do to improve students’ performance. The Personal Science Teaching Efficacy (PSTE) belief scale yields a consistently higher Cronbach’s alpha of 0.84 to 0.86 on the preoccasion and 0.89 to 0.91 on the postoccasion. That is to say, students respond in consistent ways about their “confidence” to teach science. In addition, as students interact with the subjects, the internal consistency of the STOE scale rises indicating that their responses become more consistent as time passes. The STEBI-B data were collected over an eight–year period as an illustration of students’ growth in “confidence” (Personal Science Teaching Efficacy (PSTE) belief) as well as tracking their belief that particular teacher behaviours can lead to better outcomes for students: the Science Teaching Outcome Efficacy (STOE) belief.

When we first introduced this instrument, we hypothesised that Subject 1 was likely to lead to a major reduction in the PSTE–belief scale score especially since what students thought they knew had been challenged and that their reasoning had been shown to be based on alternative scientific conceptions. We had further hypothesised that the STOE–belief scale score would show greater and positive changes because of the educational design where they began to experience personal success in learning science through our efforts and the design of Subject 1. That is to say, they were in a class where their instructors were modelling for them many approaches that appeared to covary with their perceived increases in competence.

They might have also come to perceive that good educational design and deep approaches to learning could generate the outcomes for their future
students. This may have given them a level of assurance to invest in their own efforts to learn the science and how to teach it. We were surprised to find that the first hypothesis was wrong. In fact, there were positive, albeit small, changes in the PSTE scores during Subject 1. These changes became large in Subject 2 and especially after their in-school experience. The STOE belief showed consistent and significant growth when they were involved in both subjects.

The interaction between these two constructs was inferred from our observations that once the students understood that they could actually learn the difficult area of science covered in depth in Subject 1 (viz., the astronomy content), albeit at an primary-school level, it seemed to engender a sense of confidence that they could learn other primary-school science content and that they might thus become competent in learning and teaching the science contained in any of the content areas of the Science Syllabus. These inferences were confirmed in a deep investigation conducted within Subject 1 in 2010 where students completed the STEBI–B almost on a weekly basis (10 times in 14 weeks) and through interviews conducted on a biweekly basis with a sample (6) drawn from across the different classes (Cross 2011). In 2011, the same cohort completed the STEBI-B a further eight times. This was the only cohort of students to complete the instrument multiple times. To reiterate, all other cohorts since 2007 completed the STEBI-B only at the commencement and end of each semester of their studies in science and science methods (four times over two years).

Their emerging confidence is strengthened within Subject 2 where the content areas are deliberately chosen so that they do not include any aspects of the Space Science (astronomy) covered in Subject 1. Evidence for this
interaction between the STOE and the PSTE beliefs is perhaps present in the PSTE scores in Subject 2 when they are required to go into schools to teach aspects of their Unit of Work. Indeed, in the second deep investigation conducted during 2011 with the same 2010 cohort of students, a highly significant increase in the PSTE–belief score happened in a very brief period of time (one week) and which covaried with their in–school experience when they realised the impact that the teaching of their materials had had on the school students.

**Results in Brief**

The results presented here have been collected over the 10 years that this Action Research project has been in operation. Table 1 presents the effect sizes (Cohen’s d) of three scales constructed from the ADT administered at the start of Subject 1 and again at its conclusion. It should be noted, however, that the second administration of the ADT is slightly different to the first insofar as the concepts tested are exactly the same but the questions explore different aspects of the same phenomenon. The responses made by students requires them to engage with the *Elaboration* phase of the scientific concept in the 5Es instructional model (Bybee 1997). The 5Es model is the constructivist model, imbedded within the PrimaryConnections, for planning and implementing science perspectives and content into the primary science curriculum (Bybee, 1997). The model is divided into 5 phases: Engage, Explore, Explain, Elaborate and Evaluate. Central to this model is the teacher’s role as learning facilitator. For example, in the first administration of the ADT, a question might ask “If the Earth’s orbit were changed to be exactly circular, what effect would this change have on the seasons?” while in the second administration that question would be “If the Earth’s axis of
rotation was changed to be at right angles to its orbit around the Sun, what
effect would this change have on the seasons?” Marks are awarded for the
answer plus a valid scientific reason for that answer. Other questions contain
overlays that require “visualisation”, for example, in the pretest one question
asks “Draw a picture to show how the Moon, Earth and Sun move” while in
the posttest the question is reframed as “Draw a picture to show how the
Moon, Earth and Sun move from the perspective that you are in a spaceship
high above the Earth’s south pole.”

Thus, the pre– and post–ADTs are not strictly parallel. In essence, the
post–version can be described as more difficult. Thus, the effect sizes
reported in Table 1 are likely to be underestimates of the “true effect” if
exactly the same content test had been used on both the pre- and post-
occasions. We make no apology for this since the assessment frame demands
that the students demonstrate their competence within this subject and which
adheres to the Bologna Model for Higher Education. The large effect sizes
illustrate the extent to which changes covaried with the students’ presence in
the class. The negative effective sizes for Alternative Conceptions indicates
that the number of these reduced significantly from the pre- to the post-
occasion of testing.

Table 1 Effect Sizes of the Content Knowledge, Alternative Conceptions, Complexity of
Scientific Explanation in the Astronomy Diagnostic Test – Indicators of Competence

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</thead>
<tbody>
<tr>
<td>Content Knowledge</td>
<td>2.13</td>
<td>1.08</td>
<td>5.95</td>
<td>5.75</td>
<td>2.69</td>
<td>2.41</td>
<td>4.50</td>
<td>4.24</td>
<td>4.12</td>
</tr>
<tr>
<td>Alternative conceptions</td>
<td>−0.7</td>
<td>−0.9</td>
<td>−1.9</td>
<td>−2.5</td>
<td>−1.8</td>
<td>−2.3</td>
<td>−2.4</td>
<td>−1.9</td>
<td>−1.5</td>
</tr>
<tr>
<td>Complexity of</td>
<td>1.29</td>
<td>0.78</td>
<td>5.08</td>
<td>5.15</td>
<td>3.53</td>
<td>1.97</td>
<td>2.17</td>
<td>2.43</td>
<td>2.37</td>
</tr>
</tbody>
</table>
In educational research, to achieve a change of 0.7 sigma is notable where an effect size of 0.7 – 0.8 in is normally described as “strong” (Burns, 2000). To achieve changes of 1, 2, 5 and 6 sigma, as evident in Table 1, is testimony to the robustness of the educational design of the subject. It must also be said, however, that when one starts from a lowly mean of approximately 1.5 on the preoccasion of testing, the large to very large effect sizes in content knowledge are not unexpected.

Encouraged by the 2–sigma effect in the first year of the Action Research project, we were somewhat disappointed by the 1–sigma effect obtained in the second year as far as Content Knowledge was concerned. In analysing the projects that the groups had undertaken, we noted that they had chosen to avoid those that contained difficult science concepts (e.g., phases of the Moon and the seasons) and had instead chosen those that they perceived to be easy or those with which they felt comfortable (e.g., writing a myth about a constellation or a poem about some astronomical phenomenon). That is to say, they avoided those projects that dealt directly with their alternative conceptions. Many described these projects as “too hard” for them. Thus in the third year, we provided a map from the questions in the ADT to the projects that they must do if they got the answer “wrong” on the pretest. This action had a dramatic effect on their performance on the posttest version of the ADT together with a dramatic improvement in the quality of their scientific explanations for the various phenomena. The variability in the

<table>
<thead>
<tr>
<th>N for paired data</th>
<th>81</th>
<th>89</th>
<th>99</th>
<th>95</th>
<th>72</th>
<th>108</th>
<th>40</th>
<th>73</th>
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effect sizes from year to year we find more difficult to explain. It may be due
to the varying interests of students, to varying ability, to differences amongst
cohorts, or to something that we have not yet identified. The 2010 cohort, for
example, we identified as the weakest for some time yet they still achieved at
a high level as indicated by the effect sizes greater than 2.00 for content
knowledge and a significant reduction in alternative conceptions, and an
effect size of almost 2.00 for the scientific reasons given for their answers.

Initially, for the two STEBI scales, we had intended to compute a
multivariate analysis of variance with repeated measures on the occasion of
testing using cohort membership as the independent variable. Unfortunately,
when we checked the mathematical assumptions, the Box’s-M statistic was
highly significant. We decided not to transform the data given the variation
across scales and cohorts. For each of the two scales, we proceeded to
compute separate ANOVAs with repeated measures on the occasion of testing
for each complete set of cohort data whilst also checking that the
mathematical assumptions were met. A modified Bonferroni adjustment was
employed given that six separate ANOVAS were computed for each of the
two scales (i.e., 12 computations) and given that the average inter-scale
correlation of 0.45 to yield a p-value of 0.01275 below which any differences
can be deemed to be significant. Tables 2 and 3 present the descriptive
statistics with effect sizes and levels of significance for the PSTE and STOE
scales, respectively. No data were collected from the 2006/7 cohort in Subject
1 and data for Subject 2 experienced by the 2011/12 cohort is missing.
Statistically significant increases to the PSTE subscales with moderate to
strong effect sizes were reported on all but two iterations of Subject 1 (2007
and 2009) where very small effect sizes were detected.
We note that between the end of Subject 1 in their first semester and the start of their fourth semester during which Subject 2 runs, there was a significant decrease in both the PSTE and STOE scale scores. We were curious about this reduction and investigated it through informal interviews with students. One indicator seemed to be repeated. Very few students had seen or experienced any science teaching in the interim period when they had undertaken their professional experience in schools. Perhaps this is one reason for the fall in PSTE and STOE beliefs. Others may be at play, for example, the changes in belief may not be stable when students do not have access to the subjects described here. We are investigating this hypothesis through following our graduates after they have completed these subjects and also after they have become teachers. The indications are that the PSTE belief continues to grow as they experiment and trial units of work with students in schools during their practicum sessions. Indeed, the PSTE belief appears to

### Table 2 PSTE descriptive statistics with effect sizes and significance

| Year | PSTE Subject 1 | | | PSTE Subject 2 | | | | Overall | | |
|------|----------------|---|---|----------------|---|---|---|---|
| Pre Occasion | Post Occasion | ES/Sig | | Pre Occasion | Post Occasion | ES/Sig | | Cohen's d | N |
| Mean | Std. Dev. | Mean | Std. Dev. | | Mean | Std. Dev. | Mean | Std. Dev. | | |
| 2006-2007 | - | - | - | - | - | - | - | - | - | - |
| 2007-2008 | 26.15 | 4.46 | 26.79 | 4.85 | 0.14** | 99 | 26.29 | 4.81 | 29.88 | 4.42 | 0.77*** | 76 | 0.84*** |
| 2008-2009 | 26.12 | 4.41 | 27.10 | 4.42 | 0.59*** | 95 | 27.51 | 4.42 | 29.95 | 4.80 | 0.53** | 58 | 0.83*** |
| 2009-2010 | 27.65 | 4.55 | 27.76 | 4.80 | 0.02# | 72 | 26.33 | 3.83 | 29.10 | 5.77 | 0.57*** | 42 | 0.28* |
| 2010-2011 | 26.09 | 4.11 | 28.39 | 5.77 | 0.46** | 108 | 27.67 | 4.66 | 29.94 | 6.23 | 0.52** | 67 | 0.73*** |
| 2011-2012 | 25.93 | 3.50 | 28.95 | 6.23 | 0.67*** | 40 | 26.51 | 3.95 | 30.37 | 3.95 | 0.63*** | 49 | 1.20*** |
| 2012-2013 | 26.06 | 3.56 | 29.22 | 3.76 | 0.86*** | 73 | 27.25 | 3.82 | 30.38 | 2.71 | 0.95*** | 16 | 1.76*** |
| All | 26.24 | 4.13 | 28.28 | 4.94 | 0.45** | 534 | 25.99 | 4.73 | 29.76 | 3.99 | 0.87*** | 367 | 0.87*** |

* p = 0.01275, ** p = 0.00255, *** p = 0.001275

### Table 3 STOE descriptive statistics with effect sizes and significance

| Year | STOE Subject 1 | | | STOE Subject 2 | | | | Overall | | |
|------|----------------|---|---|----------------|---|---|---|---|
| Pre Occasion | Post Occasion | ES/Sig | | Pre Occasion | Post Occasion | ES/Sig | | Cohen's d | N |
| Mean | Std. Dev. | Mean | Std. Dev. | | Mean | Std. Dev. | Mean | Std. Dev. | | |
| 2006-2007 | - | - | - | - | - | - | - | - | - | - |
| 2007-2008 | 27.63 | 3.77 | 30.26 | 3.84 | 0.69*** | 99 | 29.57 | 3.05 | 30.74 | 3.58 | 0.57** | 76 | 0.85*** |
| 2008-2009 | 27.48 | 3.18 | 30.45 | 3.43 | 0.87*** | 95 | 30.78 | 2.99 | 31.26 | 3.28 | 0.14** | 55 | 1.14*** |
| 2009-2010 | 29.13 | 2.27 | 30.94 | 3.26 | 0.38** | 72 | 30.29 | 2.87 | 31.36 | 3.15 | 0.86* | 42 | 0.69** |
| 2010-2011 | 28.51 | 3.48 | 31.32 | 3.47 | 0.81*** | 108 | 29.46 | 3.81 | 31.96 | 3.53 | 0.68** | 67 | 0.98*** |
| 2011-2012 | 29.95 | 2.91 | 31.95 | 3.61 | 0.61** | 73 | 30.99 | 3.47 | 32.77 | 3.94 | 0.49** | 49 | 0.81*** |
| 2012-2013 | 29.66 | 3.63 | 31.81 | 3.77 | 0.58** | 73 | 30.81 | 3.47 | 32.13 | 3.43 | 0.38* | 58 | 0.70*** |
| All | 28.64 | 3.54 | 31.17 | 3.66 | 0.70*** | 534 | 30.08 | 3.37 | 31.38 | 3.46 | 0.38** | 367 | 0.78*** |

* p = 0.01275, ** p = 0.00255, *** p = 0.001275
increase beyond the STOE belief achieved within these subjects. In addition, it appears that these increases in PSTE belief continue beyond their university studies and into their teaching careers (Deehan, Danaia & McKinnon, 2016).

Discussion
Successive Australian government reports and international research literature recognise the importance of science in the primary-school curriculum. The generalist nature of teaching in the primary school is, however, a problem for the teaching of science in Australian schools. Tytler et al. (2008) identify both supports and barriers to science, technology, engineering and mathematics engagement in the middle years of schooling (upper primary and junior high). They also identify pedagogy as being one key element in engaging students. Appleton (2003) focuses on the need for competent and confident primary-school teachers. Many primary-school teachers perceive themselves to possess neither of these two attributes. We argue that preservice primary-teacher education faces a major challenge to generate and to build the competence and confidence of our future teachers if they are to remain generalists who will teach primary-school science as well as the other curriculum areas.

Recent Australian discussions have indicated a preference for producing specialist primary-school science teachers and to locate one within each school. We regard this as problematic given the opportunities that science and technology present for integration with other curriculum areas, for example, with mathematics and English as well as the creative arts and social sciences. Certainly, the specialist high school science teachers have not experienced concomitant success in Australia as indicated by Year 8 and 9 performance in PISA and TIMMS data (Thomson et al., 2016). For primary-
school science, it could be argued that employing specialist teachers will further separate ‘school science’ from the ‘real world’ where scientific literacy is required as well as denying opportunities for curriculum integration. Indeed, specialist science teachers in the primary school rely on understandings developed in English and Mathematics as well as other curriculum areas.

Bybee’s (2014) article thus comes at an appropriate time in our country when we have been encountering the same problems of falling, or static, achievements in both PISA and TIMMS performance in Years 4, 8 and 9 while trying to develop strategies not only to counter this but also encourage more young people to undertake studies in science, technology, engineering and mathematics. We agree with both Tytler (2007) and Bybee (2014) who claim that teacher educators have to re–tune, replace, reform or even re–imagine science education in light of the publication of the Next Generation Science Standards in 2013 in the United States of America. We argue that these standards will require integrated approaches to the message systems of curriculum, pedagogy and evaluation (Bernstein, 1971) rather than the fine tuning of the extant practice of Education Faculty who focus on how to teach specific and different science topics each week while the science content is taught by Science Faculty in isolation from the instructional methods needed to teach it.

In this paper, we have presented an educational design model that emerged from the interrogation of our practice and which involves the students in deep, intense learning experiences, through integrating disciplinary knowledge with scientific practices, investigations and activities.
We have taken this approach one step further by integrating the instructional strategies of how to implement the content within educational settings and within the investigations and activities that are driven by that content. The evidence that we have gathered during our 10–year participatory action research project, and which we have presented in a summary fashion here, serves to support what Bybee (2014) is asking of science educators albeit at the primary-school preservice teacher–education level, i.e., “the reform of science teacher education should begin with the innovations of NGSS” (Bybee 2014, p. 219). It must be stated, however, that our design is not a retrofit to Bybee (2014). Rather, it is an outcome of a deep scholarly approach that has occurred within a participatory action research frame and driven by the authors’ desires to see more and better science taught in primary schools.

In interrogating our practice, an explanatory model emerged comprising three key design elements that employ PCK as the mediating domain of students’ interactions with the elements in mutually supportive ways. At the same time, the ‘model in operation’ involves a number of other well established approaches such as cooperative learning strategies, problem–based learning, formative feedback mechanisms and backward mapping of the assessment items to the learning experiences.

Our approach in Subject 2 suggests that the model can work in any science–content domain. Consequently, we would argue that any science area could be used as the vehicle in Subject 1 to drive students’ interactions with the relevant content. Thus, the model could be used more widely within other science domains, for example, force and motion, chemistry, the living world or in environmental science. Currently, we are involved in a project that
involves ecology and sustainability to test this claim. Certainly, what has to happen is to remove the teaching of the science from the domain controlled by a Faculty of Science who lack the pedagogical insights of how science should be implemented in primary schools and to locate it within the sphere of influence of Faculties of Education. This move, of course, has important implications for extant practice in universities if Bybee’s (2014, p. 217) assertions about the educational shifts are to happen.

When we visit other universities, we find that Primary School Teacher Professional Standards defined by various national bodies coupled with accreditation processes drive an interpretation that Science Faculty should be responsible for teaching the science content. This is entirely problematic given Bybee’s (2014) analysis. Historically, in the education domain we have had the “how to teach A” and “how to teach B” approach described by Bybee (2014, p. 219) which clearly does not work in developing the greater senses of competence and confidence described by Appleton (2003, 2007).

What we are suggesting is to narrow the science content domain whilst also implementing the “how to teach it” component that Faculties of Education have adopted so that the “new” subject is like a hybrid of going deep in both the science and education domains simultaneously. The argument here is twofold: “less is more” and, once the preservice teachers understand that they can learn the science it produces an enduring sense of competence. We are currently investigating this endurance factor by following students in their third and fourth years of university and beyond when they are employed as primary-school teachers. Evidence shows that the
effects reported here maintain, and indeed grow, beyond the end of their university studies and into their teaching careers.

One clear implication from the approach described here is that the Education Faculty will have to be staffed with members who are very good in at least one science discipline in order to implement the model presented above and be experts in the teaching of that domain. Alternatively, if scientists are to teach preservice primary-school teachers they will have to be well versed in pedagogy and the use of effective instructional strategies at the primary-school level as well as in the assessment and evaluation of what they implement. A final possibility lies in the formation of collaborative teams of scientists and science education experts to deliver the content using appropriate learning experiences to generate the high levels of competence and confidence required of our primary-school teachers when they enter the profession and to arrest the declines in primary-school science performance.
References


Connective Statement Two

The previous publication entitled “The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model” (McKinnon, Danaia & Deehan, 2016) described the context within which two science education courses (SC108 and SC308) were developed and refined. Such narrative descriptions certainly fill a gap in a literature base where the process of course design is seldom provided in favour of broad outlines of finished courses. The extended vignettes serve as replicable examples of how pedagogical content knowledge (PCK) can serve as a mediating framework to ensure multiple innovative practices are combined to form cohesive and meaningful science education learning experiences for preservice teachers. The important role of PCK is exemplified in the emergent Interactive Educational Design Model (IEDM) where it interacts with science content, feedback systems and significant others (educators, researchers and preservice teachers). Within the IEDM PCK is operationalised to include: knowledge about alternative scientific conceptions, knowledge of educational contexts, beliefs about the purpose of science education, cooperative learning, instructional strategies and science content knowledge. In short, at the beginning of the SC108 course preservice teachers identified their astronomy alternative conceptions, which they went on to address through inquiry and cooperative microteaching. Through the application and continued development of the core scientific skills developed in SC108 participants were able create and test science curricula focusing on different content areas in SC308. While the rich educational design description presented in the prior publication is a strong, stand-alone inclusion in the wider body of science education literature, deeper insights
and statistical evidence are required to validate the design of the science courses (SC108 and SC308).

The next publication entitled “A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers” (Deehan, Danaia & McKinnon, 2016) extends on the descriptive vignettes by investigating the science teaching efficacy beliefs and experiences of a single cohort of preservice primary teachers. Rather than relying simply on a standard pre-post-test research design, the complexity of the SC108 and SC308 courses are investigated through two complementary mixed methods case studies with weekly administrations of the STEBI-B instrument (see appendix 4, p.387) to allow for more rigorous tracking of participants’ science teaching efficacy beliefs. It is recognised that the science courses exist within broader educational contexts (i.e. teaching degree programs) and thus the research to follow utilises an extended delay testing period of 2-years after the completion of the science education program to ascertain the durability of any changes to STEBs. The rigorous mixed methods, investigation of a cohort of preservice teachers’ STEBs is a meaningful and valuable contribution to the STEBI literature both in terms of knowledge generated (assessment of a complex, innovative science education program) and research methods used (weekly STEBI-B administrations and longitudinal research). The next publication also advances the narrative of this doctoral dissertation by providing evidence to clearly place the aforementioned science courses (publication two) within the established field of STEBI literature (publication one).
Publication Three

A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers

Publication three has been submitted to the International Journal of Science Education (see appendix 8, p.399). Language and formatting have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Research Conceptualisation
- Data Collection
- Data Analysis
- Manuscript Drafting
- Manuscript Editing
A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers

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2School of Education, Edith Cowan University, Perth, WA, Australia.

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James Deehan – James graduated with a first class Honours degree from the Bachelor of Education (Primary) course in 2012. Since graduating James has worked casually in primary schools in the Bathurst region, with particular focuses on science education, gifted and talented education and small school education. The subject of James’ Honours thesis was how the EMS308 subject designed influenced the science teaching efficacy beliefs of a cohort of preservice primary teachers. In 2013 James was offered an Australian Postgraduate award to complete a PhD at CSU Bathurst. In his PhD research, James aims to determine how the science subjects offered at CSU influence the science teaching efficacy beliefs and science teaching practices of early career primary teachers. James is a mixed methodologist with an interest in how qualitative and qualitative research can be used in a complementary way. He has published journal articles, opinion-editorial articles and a book.

Dr. Lena Danaia – Lena Danaia is an academic within the School of Teacher Education at Charles Sturt University. She specialises in the science curriculum area. Lena previously worked as a teacher in both Australia and the United Kingdom. Lena’s research in science education spans primary, secondary and tertiary contexts and has involved her working on a number of projects with a range of stakeholders. Lena’s PhD, which was awarded in 2008, focussed on students’ perceptions of and performance in secondary school science both before and after their involvement in a project that fostered investigative, inquiry-based approaches in science teaching and learning and which provided students and teachers with the opportunity to control a telescope in real-time over the Internet. Lena has been recognised nationally for her outstanding contributions to learning and teaching in science where she was awarded an Australian Learning and Teaching Council (ALTC) Teaching Excellence Award.
**Prof. David McKinnon** - David McKinnon is a Professor of Education at Edith Cowan University at Joondalup in Western Australia. He established and ran the Charles Sturt University Remote Telescope until his departure in July 2014. He has a profound interest in science education at all levels and especially involving astronomy, public outreach and teacher professional learning. He has been involved with Las Cumbres Observatory global telescope network and its predecessor Faulkes Telescopes UK since 2003 as an international education advisor and consultant as well as undertaking research into the impact of using the telescopes on students and teachers.
A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers

Abstract

This paper assesses the relationship between participation in two tertiary science subjects and the science teaching efficacy beliefs (STEBs) of one cohort of preservice primary teachers over a four year period. Two Type II case studies were conducted within the subjects. Data were collected through 26 administrations of the Science Teaching Efficacy Belief Instrument-B, semi structured interviews, Harvard one minute papers and subject evaluations. Results showed that participation in the subjects covaried with increases in the participants’ STEBs. These increases in STEBs remained durable for two years. Implications for these findings are discussed within the paper.

Key words: Science teaching efficacy; preservice primary teachers; primary science; preservice teacher education; longitudinal.

Introduction

The negative science attitudes of many primary teachers have been illustrated repeatedly in research literature for decades (de Laat & Watters, 1995; Mulholland, Dorman & Odgers, 2004; Schibeci, 1984). Many teachers do not feel confident in their ability to teach science because of their inadequate science content knowledge (Palmer, 2011; Tytler, Smith, Grover & Brown, 1999). Other factors that contribute to poor science attitudes include; low Pedagogical Content Knowledge, negative personal educational experiences and the perceived cognitive difficulty of science content matter (Jarrett, 1999; Jurišević, Glažar, Pučko & Devetak, 2008; Nillson & Loughran, 2011; Skamp & Mueller, 2001).
Given the largely negative views of science held by primary teachers, it is unsurprising that science curricula are often marginalised and distorted (e.g., Appleton, 2003; Appleton & Kindt, 2002). During the 1990s, it was often reported that science was taught for an hour a week in Australian primary classrooms (e.g., Gough, Marshall, Matthews, Milne, Tytler & White, 1998). Later reports indicated that the average amount of time spent in primary science had decreased to 40 minutes per week (Angus, Olney, Ainley, Caldwell, Burke, Selleck, Spinks, 2004; Goodrum & Rennie, 2001). If the reports are correct, science receives 4% of the available curriculum time.

The limited science that is taught in primary schools is often teacher centric and transmissive (Goodrum & Rennie, 2007; Jarrett, 1999; Smith; 2014; Weiss, 1994). According to Kelly (2000, p.756), “what typically transpires in the science classroom is not the hands on minds on paradigm that demonstrates an operations fusion of pedagogical strategy and content knowledge. Rather, science teaching is often reduced to a collection of facts, discussions about assigned readings, and an occasional activity.” Indeed note taking, completing worksheets and teacher demonstrations are common place in primary schools (Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007). In fact, many primary teachers are unaware of what constitutes ‘good’ science teaching (Appleton, 2003). This may stem from conceptually poor understanding of science PCK that leads to inappropriate pedagogical selection. Teachers often incorrectly believe that physical manipulation alone gives students control over their learning.

Longitudinal professional development programs, with ongoing support, can improve the science teaching attitudes and practices of inservice
primary teachers (Duran, Ballone-Duran & Beltyukova, 2009; Lumpe, Czerniak, Haney & Beltyukova, 2012). Tytler et al. (1999) suggested that a longitudinal approach to professional development covaries with improved science confidence and knowledge. Palmer (2011) implemented another longitudinal professional development program the results of which indicated that cognitive mastery and in situ feedback improved the science teaching efficacy of the teachers. While professional development opportunities are undoubtedly beneficial, there are considerable financial and time requirements to the provision of the embedded, longitudinal support needed to improve the science teaching efficacy and science practices of inservice primary teachers. The increasing mean age of inservice teachers may render interventions at the tertiary level in preservice teacher education programs more desirable and efficient (Harris & Farrell, 2007, NSW DEC, 2011).

A growing body of literature has shown that science interventions targeting preservice primary teachers can successfully alter negative perceptions and address knowledge deficits (Cooper, Kenny & Fraser, 2012; Deehan, 2013; Watters & Ginns, 2000). Explicit instruction on the nature of science through the use of scaffolded argument has been shown to both improve preservice teachers’ understanding of science and alleviate some of the negative views developed within their personal school experiences (McDonald, 2010). Cooperative learning, in an authentic setting, can improve both science attitudes and science teaching efficacy (Cross, 2010; Deehan, 2013; Watters & Ginns, 2000). Bleicher and Lindgren (2005) found that the use of constructivist approaches to address students’ alternate scientific conceptions produced large effect size increases (Cohen’s $d = 1.2$) in preservice teachers’ personal science teaching efficacy beliefs. Cooper,
Kenny and Fraser (2012) found that mentoring programs between preservice and inservice teachers were beneficial for both parties. It should be noted that the negative trends within primary science classrooms do not reflect the positive reports from the tertiary level. Amidst the promising results of tertiary science education programs, there is still a lack of consistency in how science is taught to prospective primary teachers (Palmer, 2008).

Palmer (2006) found that the science teaching efficacy gains made by a group of preservice primary teachers as they participated in a cooperative, inquiry based science subject remained durable for nine months after the subject had been completed. Richardson and Liang (2008) considered the durability of science teaching efficacy by utilising the delay period between science subject offerings. They found that the participants’ STEBS increased in the absence of treatment. Ginns, Tulip, Watters and Lucas (1995) used a longitudinal design to evaluate a four year preservice primary teacher education program. They found that participants’ science teaching efficacy beliefs did not improve during their undergraduate teaching preparation.

The project reported on in this paper models elements of these research studies by having delay periods between subjects to assess the durability of efficacy changes and to explore trends from over a longer time period. In addition, collecting data for two years after the end of formal classes in science education allow the longer term durability of any changes to be rigorously assessed. The aims of this research are thus threefold. The first aim is to assess the relationship between preservice primary teachers’ participation in a complex, integrated science program with two complementary subjects (SC108 and SC308) and their science teaching efficacy beliefs. The second aim is to determine if any changes to
participants’ science teaching efficacy beliefs that occur within the science program remain durable for up to two years in the absence of treatment. The third aim is to inductively explore how the participants’ attitudes towards and perceptions of science teaching develop as they progress through the science subjects and beyond.

**Theoretical Framework**

Reports of poor science content knowledge (Appleton, 1992, 2002, 2003; Howitt, 2007) and low PCK (e.g., Hechter, 2010) by primary teachers may be evidence of low confidence and self efficacy. Teachers cannot consider how their science teaching influences student outcomes until they themselves believe that their teaching practice will have the intended effects on student learning. At a basic level, self efficacy can be defined as an individual’s judgement of his or her competence to execute a task (Bandura, 1977, 1986). More specifically, self efficacy can be conceptualised as consisting of two distinct components: Personal Efficacy (PE) and Outcome Expectancy (OE). PE is an individual’s belief in his or her abilities as a teacher. OE constitutes beliefs about how much student learning depends on teacher effectiveness. Self efficacy is one of the strongest predictors of human motivation and behaviour (Bandura, 1986).

Teacher Efficacy has been found to correlate positively with desirable outcomes in both teachers and students (Goddard, Hoy & Hoy, 2000). Teacher efficacy is the confidence an individual has in themselves or their profession to help students to achieve predetermined educational outcomes (Berman, McLaughlin, Bass, Pauly & Zellman, 1977). Modelled on Bandura’s (1977, 1986) earlier work, the construct is differentiated between Personal Teaching Efficacy (PTE) and General Teaching Efficacy (GTE).
PTE describes an individual’s belief in their own ability to overcome contextually specific factors to promote student learning (Coladarci, 1992; Gordon & Debus, 2002). GTE is the belief that teaching in general can overcome external factors, such as socio-economic status, various learning needs and detrimental social experiences, to guide students towards achieving predetermined goals (Tshannen-Moran & Hoy, 2001).

Riggs and Enochs (1990) designed two science teaching efficacy instruments that were modelled on the Teacher Self Efficacy scales (TSES) produced by Gibson and Dembo (1984). The Science Teaching Efficacy Belief Instrument A (STEBI-A) was designed to measure the science teaching efficacy of inservice primary teachers (Riggs & Enochs, 1990). The Science Teaching Efficacy Belief Instrument B (STEBI-B) was designed to measure the science teaching efficacy of preservice primary teachers (Enochs & Riggs, 1990). These instruments are equivalent as the STEBI-B was designed by modifying the items from the original STEBI-A instrument to reflect the perspectives of preservice teachers. The STEBI-B is used in this research to track participants’ personal and general science teaching efficacy over the course of four years.

**Participants**

The participants in this research were a cohort of preservice primary teachers at a regional Australian university. Participants were 112 undergraduate preservice teachers enrolled in a Bachelor of Education (Primary) four year fulltime degree. This degree would provide them with the knowledge, skills and qualifications necessary to teach in Australian primary schools. The participants attended the university from 2010 through to 2013.
Due to the longitudinal nature of the research, attrition contributed to declines in response rates over time. On the first occasion of testing, 112 preservice teachers provided data. By the final occasion of testing, over four years later, 56 preservice teachers provided data. The age of the participants ranged from 18 to 55. The focus cohort commenced a four year primary teaching degree in 2010. Those who remained ‘in phase’ graduated at the end of 2013. A total of 12 members of the cohort participated in semi structured interviews.

The preservice teachers complete 32 subjects with 14 of these focussing on the six Australian primary Key Learning Areas (KLAs) and primary teaching pedagogies. As a requirement for the award of the degree the preservice primary teachers completed two science curriculum course.

**Science Courses**

The first science course ‘Science and Technology Studies I’ (SC108) was positioned in the first semester of the first year of the degree. The second science course ‘Science and Technology Curriculum Studies II’ (SC308) was completed in the second semester of the second year of the degree. Table 1 identifies the pedagogical approaches used in both subjects.

**Table 1** Pedagogical Approaches used in SC108 and SC308

<table>
<thead>
<tr>
<th>Pedagogical Approach</th>
<th>SC108</th>
<th>SC308</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructivism</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Problem Based Learning</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Project Based Learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration with other KLAs</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mentoring</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Real world relevance</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Inquiry learning</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>In subject practical experience</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Links to practical experience blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperative Learning</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>ICT Instruction</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Student Centred Investigation</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>
The knowledge and skills developed in SC108 were prerequisites for entry into the SC308 subject. SC308 moves beyond the Astronomy focus of SC108, as students were required to develop their Pedagogical Content Knowledge (Magnusson, Krajcik & Borko, 2002; Van Driel & Berry, 2010) in order to teach syllabus content effectively. A hybrid constructivist pedagogical approach was used within an extended role play where the professor acted as the principal of the school (the tutorial class) and the preservice teachers assumed roles as teachers within the school. The preservice teachers work in
cooperative learning groups throughout the semester (approximately four per group) to create a science unit of work for a different science content strand than the Earth and Space content covered in SC108. Each practical class has a different content focus and each cooperative learning group has a different stage focus (F, years 1 and 2, years 3 and 4, years 5 and 6). The cooperative learning groups are required to navigate the syllabus, research science content and make pedagogical decisions to design a teachable science unit of work. The goal of this educational paradigm was to provide the preservice primary teachers with the skills and knowledge necessary to research and adapt science concepts for the classroom. A full description of the educational design and pedagogical inclusions of the SC108 and SC308 subjects is the subject of another paper (McKinnon, Danaia & Deehan, 2016).

Methodology and Methods

Two complementary concurrent nested mixed methods, Type II case studies (Burns, 2000; Creswell, 2013; Shadish, Cook & Campbell, 2002; Yin, 2003) were conducted to explore the science experiences and STEBs of a cohort of preservice primary teachers at an Australian university. The investigation used a repeated measures design with delayed testing periods (Shadish, Cook & Campbell, 2002) to strengthen the case for covariance in the absence of an experimental design with a control group. Table 2 provides an outline of the treatment and data collection time frame. The STEBI-B instrument was administered weekly during the two science subjects, in addition to the key data collection periods presented in Table 2. This allowed for the PSTE and STOE scores to be assessed throughout the subject and subsequently cross referenced with different learning events.
Table 2 Treatment and Data Collection

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>X1</td>
<td>O2</td>
<td>O3</td>
<td>O4</td>
</tr>
<tr>
<td>O2</td>
<td>X0</td>
<td>O3</td>
<td>X1</td>
<td>X0</td>
</tr>
<tr>
<td>O3</td>
<td>X0</td>
<td>O4</td>
<td>X0</td>
<td>O5</td>
</tr>
<tr>
<td>O4</td>
<td>X0</td>
<td>O5</td>
<td>X0</td>
<td>O6</td>
</tr>
<tr>
<td>O5</td>
<td>O6</td>
<td>O7</td>
<td>O0</td>
<td>O8/G</td>
</tr>
</tbody>
</table>

- **X1**: The presence of a formal treatment intervention (SC108 or SC308).
- **X0**: A delay period where the participants are not exposed to a formal treatment, but undergo a formal practical teaching experience.
- **G**: Students graduate and enter into the teaching profession.
- **O1**: The initial data collection occurred at the beginning of the 1st semester in 2010.
- **O2**: The data collection occurred after the first treatment at the end of the 1st semester in 2010.
- **O3**: At this point, data were collected before the second treatment at the beginning of the 2nd semester in 2011.
- **O4**: The data collection occurred after the second treatment at the end of the second semester 2011.
- **O5**: This data collection occurred after a delay period at the end of the first semester in 2012.
- **O6**: This data collection occurred after a delay period at the beginning of the second semester in 2012.
- **O7**: This data collection occurred after a delay period, just prior to the final ten week teaching experience, in the second semester of 2013.
- **O8**: This data collection occurred after the cohort completed the final internship in the second semester of 2013.

Earlier iterations of both subjects indicated that there were significant events during the course of a semester which appeared to have an impact on the students. These “events” were detectable in the qualitative data provided in the form of one minute feedback papers. These feedback papers were administered once a week during each 12-week offering of SC108 and SC308. We were interested to investigate any impacts that these events may have had on their efficacy beliefs. For example, in SC308, we had observed the impact of the in-school science teaching experience on them and wished to investigate any impact that this had. Consequently, for this one cohort of students, we administered the STEBI-B on an almost weekly basis in the two subjects to generate 12 occasions in SC108 and 10 occasions in SC308 on which data were collected. Following these subjects in the students’ third and fourth years of study, a further four administrations prior to and following their in-school professional experiences were conducted to generate a total of 26 occasions.
One could argue that such frequent administration of the instrument would contaminate the data through test-retest familiarity. We were careful to explain on each administration of the STEBI-B that students should read and carefully respond to each item in light of their current feelings. Most students appeared to treat each completion of the instrument in a conscientious fashion while some made comment in their final evaluations that they never wished to see it again. Given the extensive reliability analyses, we believe that the changes in both scales are real and do not reflect any major threat to validity caused by test familiarity. The following subsections will unpack each of the data collection methods in greater depth.

The Science Teaching Efficacy Belief Instrument (B)

The Science Teaching Efficacy Belief Instrument B (STEBI-B) was used to measure the science teaching efficacy of preservice primary teachers (Enochs & Riggs, 1990). The instrument requires respondents to rate their level of agreement with statements on a 5 point Likert scale (Burns, 2000), ranging from ‘strongly disagree’ to ‘strongly agree’. The statements produce measurements on two subscales. The Science Teaching Outcome Expectancy (STOE) belief scale measures the participants’ broad views of science teaching related to why students perform as they do. The Personal Science Teaching Efficacy (PSTE) scale measures the participants’ beliefs about their own ability to teach science effectively. The items produce ordinal data as there are no observable or standardised intervals between the Likert responses of ‘strongly agree’, ‘agree’, ‘uncertain’, ‘disagree’, and ‘strongly disagree’ (Kervin, Wilma, Herrington & Okely, 2006). The seminal authors reported Cronbach’s Alpha reliability coefficients of 0.90 for the PSTE subscale and 0.76 for the STOE subscale (Enochs & Riggs, 1990).
The comparatively low reliability and external locus of the STOE subscale have emerged as contentious issues within the broader body of STEBI-B literature. The STOE subscale has been reported as having lower reliability than the PSTE subscale in a variety of contexts (e.g., Aydin & Boz, 2010; Bleicher, 2006; Riggs & Enochs, 1990; Velthuis, Fisser & Pieters, 2014). McDonnough and Matkins (2010) expressed doubt in the reliability of the STOE subscale due to the external locus of control. Indeed, others (e.g., Bursal, 2008; Hechter, 2010) believe that the sheer volume of potential influencing factors make the STOE subscale conceptually unclear. Mulholland, Dorman and Odgers (2004) believe that the items comprising the STOE subscale reflect an outdated, teacher centred mode of science teaching. They believe that inconsistency in participants’ responses can be partially attributed to an inability to relate to the items to their experiences in modern teacher preparation programs. The STOE scale is often dismissed (e.g., Andersen, Dragsted, Evans & Sorensen, 2004; Cannon & Scharmann, 1996) or merged with the PSTE subscale (e.g., Slater, Slater & Shaner, 2008). Merging subscales is a particularly inappropriate practice as it both denies the separate nature of constructs and artificially inflates alpha scores through a greater number of items (Tavakol & Dennick, 2011). The authors believe that broader contextual efficacy is necessary for an individual to persevere in their completion of a task in cases of adversity. Thus, the reliability of the STEBI-B instrument was measured repeatedly in the four year data collection period.

Although still acceptable, the reliability of the subscales appeared to be an issue early in the current research as the PSTE (Cronbach’s $\alpha = 0.73$) and the STOE (Cronbach’s $\alpha = 0.69$) reliabilities were well below those reported by seminal authors. Later investigations showed that the reliability
of the scales improved over the course of the four year data collection period. On the final occasion of testing, just prior to the cohort’s graduation, the PSTE and STOE subscales showed Cronbach’s alpha reliabilities of 0.88 and 0.87 respectively. Such equality in subscale reliability is seldom reported in the STEBI-B literature. The implications of this information will be analysed further in the discussion section of this paper.

**Semi Structured Interviews**

The semi structured interviews within the current research explored the science experiences, perceptions, beliefs and opinions of selected preservice primary teachers in relation to their participation in the science curriculum subjects (SC108/ SC308) and their emerging capacities as science teachers. Initially, a stratified sampling technique was employed wherein representatives of four categories based on STEBI-B scores were sought. The four categories were: Disillusioned (Low PSTE/ Low STOE); Stressed (Low PSTE/ High STOE); Cynical (High PSTE/ Low STOE); and Confident (High PSTE/ High STOE). Ultimately, a combination of convenience and snowball sampling procedures were used to gain access to willing participants. Repeated semi structured interviews were conducted with 12 participants, during the delivery of SC108, SC308 and on the one delayed testing occasion.

**Harvard One Minute Paper**

The Harvard one minute paper is a concise survey which allows teachers to evaluate their learning experiences ‘in the moment’ (Chizmar & Ostrosky, 1998). These were administered after each tutorial in SC108 and SC308 to evaluate participants’ conceptual understanding of and emotional responses to the treatments in the two semesters. The instrument consists of five items: what worked for me in this tutorial; what could have been improved for me
in this tutorial; list three things you learned in this tutorial; list three things
you need to learn more about; and, list 5 words to describe how you currently
feel.

Subject Evaluation Comments

At the end of each subject, the participants responded to open ended subject
evaluations. Participants were called upon to write a general comment about
their experiences in the subjects or make suggestions for the improvement of
the subjects. Table 3 summarises the data collection practices throughout the
research project.

Table 3 Data Collection Instrument Use by Period

<table>
<thead>
<tr>
<th>Instrument Use by Period</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEBI-B</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>Semi-structured Interview</td>
<td>O</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvard 1 minute papers</td>
<td>O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject Evaluation Comments</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Analyses

For the STEBI-B data, Multivariate Analysis of Variance (MANOVA) with
repeated measures on the occasion of testing were computed to determine if
the PSTE and STOE scores of participants changed over the four year period
(Coleman & Pilford, 2008). Cohen’s d was computed to determine the effect
sizes of any STEB changes occurring over time. In addition, SPSS statistical
software was used to analyse and produce descriptive statistics, tests for the
homogeneity of variance and tests for the equality of the covariance matrices
to ensure that the distributions of the DVs met the mathematical assumptions of MANOVA.

All qualitative data were transcribed and manually analysed both anecdotally and thematically by the lead author. This provided a holistic, contextually bound understanding of the data. The next step was to recode the data for consistency and clarity without altering the meaning of the text. To avoid bias and researcher error, these analyses were supplemented with a computer analysis using Leximancer software. The Leximancer software was used to conduct broad, syntactical analyses of the text to identify themes and to explore thematic relationships. This semantic analysis serves as a useful complement to the researcher’s personal identification of themes and is a good test for the validity of interpretation.

**Results**

Due to the longitudinal nature of the research, the results are presented by the year of data collection. Background information and qualitative data will be used to provide the context needed to establish a narrative within this section.

**2010 – First year**

The participants began their degrees in the first semester of 2010 during which they completed the SC108 science subject. The students completed eight subjects during 2010. At the midpoint of the second semester, the preservice teachers completed their first practical teaching experience placement of two weeks where they were required to observe an inservice teacher and to teach small groups of students and to plan for and teach five single lessons.

When the preservice teachers commenced their tertiary studies in SC108, they possessed ‘unrealistic’ science teaching efficacy beliefs relative
to their lack of formal experience as educators. At the first lecture, 72 students reported high efficacies in both their own capacity to deliver quality science education to students (PSTE) and in the capacity of science teaching to help students to achieve learning outcomes in a broader sense (STOE). Curiously, they held these beliefs despite having experienced no formal teacher training and had limited backgrounds in science education.

In the first practical class, students had to complete a test which assessed the Astronomy content knowledge that they would be expected to teach to years 3 and 4 students (8-9 year old children). The preservice teachers scored badly in both the quality and complexity of their written responses. Interviews revealed that the preservice teachers were deeply affected by their poor performance. For example:

**Lara:** I did really badly in the ADT. At the moment I am really scared. It's very daunting. It makes me question whether this is actually what I want to do. Even when (the professor) was writing the answers up, I was questioning it. It was like no, no, no – this is what I’ve thought for years.

**Christy:** It’s a big realisation of how much work it’s going to be, to get to know the content.

**Larry:** I am prepared, but not confident. Some of the questions I was a bit more sure of turned out to be wrong. (The professor) explained that’s the way a lot of people think. It sort of made me feel better.

**Malcolm:** It means I’ve got to really address my knowledge and come up to the plate if I want to be an effective teacher.

As the preservice teachers began to engage with the research literature, group activities and micro teaching, their classroom attitudes seemed to improve. Figure 1 shows the preservice teachers’ use of negative words (e.g. ‘scary’, ‘difficult’, ‘frightening’) in their one minute paper responses for the first six weeks of the semester. As they engaged with the materials and became aware
that their limited knowledge was common, the negative responses decreased. There were still some negative responses as the students adjusted to their prospective role as teachers and completed homework and introductory assessment tasks during weeks two and three. However, by week four there were very few negative responses as the preservice teachers became more comfortable in the problem based learning environment. Common words such as ‘fun’, ‘interesting’, ‘enjoyable’, ‘interactive’, ‘educational’ and ‘constructive’ show that the preservice teachers felt personal enjoyment and valued their educational experiences.

![Figure 1 Harvard One minute paper – Negative Word Counts per Week](image)

Positive trends were also evident in the science teaching efficacy of the cohort throughout the semester. Figure 2 shows the mean PSTE and STOE scores of the participants as they progressed through the SC108 subject. There was a consistent, if uneven, increase in both subscales throughout the subject. Of note is the finding that the STOE means were higher than the PSTE means on all occasions of testing. This is an anomaly as the PSTE is almost always higher than the STOE subscale in the STEBI-B literature (Deehan, 2016). The PSTE showed a moderate effect size increase (Cohen’s d = 0.41). The STOE
subscale showed a large effect size increase (Cohen’s d = 0.79).

Figure 2 SC108 – Mean STEB scores by week

Table 4 presents the results for the MANOVA conducted on the pre to post occasion STEB data collected in SC108. There is a significant main effect due to the occasion of testing (F(1,107)=52.94, p < .0001). This indicates that the PSTE and STOE scores of the participants showed a statistically significant increase as they undertook the SC108 subject. There is also a significant main effect due to the variables, PSTE versus STOE (F(1,107)=42.85, p < .0001). A possible interpretation may be that the preservice teachers did not yet feel confident that they could personally fulfil their own broader expectations of science teaching to improve student outcomes. There was no significant interaction effect due to occasion with variable (F(1,107)=0.75, p = .389).

Table 4 MANOVA of STEB data collected during the SC108 subject

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occasion</td>
<td>702.78</td>
<td>1</td>
<td>702.78</td>
<td>52.94</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>1420.47</td>
<td>107</td>
<td>13.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>770.67</td>
<td>1</td>
<td>770.67</td>
<td>42.85</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(Variable)</td>
<td>1924.58</td>
<td>107</td>
<td>17.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * Variable</td>
<td>7.00</td>
<td>1</td>
<td>7.00</td>
<td>.75</td>
<td>.389</td>
</tr>
<tr>
<td>Error(Occasion*Variable)</td>
<td>1002.25</td>
<td>107</td>
<td>9.37</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The semi structured interview data reveal that by the end of SC108 the preservice teachers seemed to be more confident in their ability to teach science. They attributed their changed attitudes to components of the educational design that underpinned the SC108 subject. For example:

**Malcolm:** The big moment where I realised that I’d actually be confident teaching, like last night when I realised exactly how much I’d sort of done in the subject. I read through my assignment and went, it’s all for a reason. The curriculum building, the readings we did, the extra homework, all the cooperative learning strategies that we did in class. It all sort of came together in my head last night. I sort of had an epiphany thing, where I realised how useful this subject is, to us going teaching. It’s built my confidence up something fierce.

**Aaron:** I think it is the micro teaching part. We were able to put theory into practice, if you get what I mean. We learned about teaching strategies, we read and learned content knowledge and then we were able to put this into practice by trying and teaching the stuff. It was like I am going to try this, and I did, then it was like, hey that was brilliant or hey, no that sucked, what could I do to improve that?

**Lara:** Science is better than I thought it was! I hated him, and I hated it, at the start and I like it now. I am actually really glad that I got to do that class, because it really isn’t that bad. It’s actually really brilliant how he set it out. It’s very beneficial because you learn so much from it. I don’t know, it was just so brilliant. Like, oh God, it’s hard to hate a brilliant man.

**2011 – Second Year**

The preservice teacher cohort entered its second year of the degree in 2011. The participants experienced their final science subject, SC308, in the second semester of that year. Since completing SC108, the participants had completed an additional eight subjects and a two week practical teaching placement. After the second subject, the preservice teachers undertook a four week practical teaching placement in pairs. They completed multiple lessons across all curriculum areas as they worked towards undertaking a full
teaching load in the final week. The preservice teacher pairs were still supervised and guided by an inservice teacher.

In the 12 month period between the end of SC108 and the beginning of SC308 the STEBs of the preservice teachers declined. The PSTE declined by a small Cohen’s d effect size of 0.12. More troubling was the moderate STOE decline (Cohen’s d = 0.56). A MANOVA with repeated measures revealed that the decline in both the PSTE and STOE by occasion were significant (F(1,61)=9.71, p = .003). The decline in the STOE may be related to the preservice teachers’ observations on their first practical teaching experiences. The marginalisation of science in schools was a prominent theme in the semi structured interviews. For example, responding to the question “Did you see any science being taught at your school?” the following were elicited:

**Edward**: I’m pretty sure that there was no science taught. I’m pretty sure that it was embedded in there, but I didn’t see it there.

**Bec**: No! Not one bit of science at all.

**Daisy**: No, no (science). None whatsoever.

**Connie**: I taught a couple of lessons which were called ‘Science’, but I wouldn’t call them Science. They’d just done happy healthy Harold. They were lessons that were sort of half health, half science. They were about food groups and what goes into certain food groups. They called them ‘Science lessons’, but they didn’t have a lot to do with the science curriculum.

**Fiona**: (Um) I honestly don’t think so. I think it happened when we had release time, like relief from face to face [teaching], so I had to go with my associate then. So I never actually saw science being taught.

The initial phases of the second semester of science methods were tumultuous, as they adjusted to the complex, rigorous demands of SC308, but ultimately positive as the students developed their Pedagogical Content Knowledge (PCK) through the collaborative construction of a science unit of
work (UoW). Figure 3 shows the changes in response to the Harvard one
minute paper between weeks one (represented by the dark grey columns) and
six (light grey columns). The preservice teachers started the semester with
negative views as they were overwhelmed and stressed by the requirements
of the subject. However, by week six the preservice teachers were pleased
with their science learning as words such as ‘happy’, ‘organised’, ‘excited’
and ‘relieved’ became more prominent in their responses. Figure 3 illustrates
the sizeable reduction in the frequency of negative responses.

![Figure 3: Emotional Responses as Measured by the Harvard One Minute paper - Week One and Week Six]

The trend of growth in the science teaching efficacy beliefs of the preservice
teachers continued as they worked through SC308. Figure 4 shows the mean
PSTE and STOE scores of the participants for each occasion of testing in the
SC308 subject. There was an unprecedented increase of the PSTE scale
during the eighth week of the semester. The increase coincided with the
preservice teachers’ participation in a science teaching day where they taught
some of the contents of their unit of work to groups of students drawn from a
number of local schools. Overall, the PSTE subscale showed a moderate
effect size increase (Cohen’s $d = 0.61$). The STOE subscale underwent a
similar increase (Cohen’s $d = 0.68$) during the SC308 subject.

![Figure 4 SC308 - Mean STEB Scores by Week](image)

There were highly significant changes over time in both the PSTE and STOE scores. Table 5 shows the statistical output for the MANOVA conducted on the SC308 STEB data. There is a significant main effect due to the occasion of testing ($F(1,66)=60.24$, $p < .0001$). There is also a significant main effect due to the variables, PSTE versus STOE ($F(1,66)=25.01$, $p < .0001$). That is to say, the gap between their outcome expectancies and personal science teaching efficacy beliefs remained present throughout the SC308 subject. There was no significant interaction effect due to occasion with variable ($F(1,66)=0.29$, $p = .590$).

**Table 5** MANOVA of STEB data collected during the SC308 subject

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occasion</td>
<td>480.90</td>
<td>1</td>
<td>480.90</td>
<td>60.24</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>526.85</td>
<td>66</td>
<td>7.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEB</td>
<td>324.72</td>
<td>1</td>
<td>324.72</td>
<td>25.01</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>857.03</td>
<td>66</td>
<td>12.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>2.33</td>
<td>1</td>
<td>2.33</td>
<td>.29</td>
<td>.59</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>525.42</td>
<td>66</td>
<td>7.96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The learning experiences within the SC308 had a profound effect on the
participants. They developed practical inquiry skills that would enable them to plan and teach quality science lessons. One interviewee discussed her development during the SC308 subject:

Daisy: The fact that I have completed a whole unit of work makes me realise that I can actually teach science. The kids can get hands on, the experiments, they can see the answer for themselves while doing something hands on. It’s really great and I hope when I go on prac that one of the lessons that I will teach will be science.

2012 – Third Year

For the targeted cohort of preservice teachers, 2012 was their third year of tertiary study. The cohort participated in no formal science education during this period. The purpose of data collection at this time was to determine the durability of attitude and STEB changes that occurred during the first two years of their degree. The preservice teachers completed a five week individual practical teaching placement at the end of their fifth semester of study. Prior to going on the practical teaching placement, the cohort again completed the STEBI-B instrument and again at the start of the following semester on return to university.

The preservice teachers’ science teaching efficacy beliefs remained stable during that year with no formal science intervention. Table 6 shows the descriptive statistics for the STEB scales collected at the end of SC308, prior to and following the practical teaching placement (delay period 1 and delay period 2). Clearly, there was very little change in their science teaching efficacy beliefs despite no formal science education for a year. A MANOVA with repeated measures showed that there was no significant difference in participants’ STEBs on the occasion of testing (F(1.29)=1.98, p = .167) during this period.
Table 6 Descriptive Statistics for the End SC308, Delay Period 1 and Delay Period 2

<table>
<thead>
<tr>
<th>Occasion</th>
<th>PSTE Occasion</th>
<th>M</th>
<th>SD</th>
<th>STOE Occasion</th>
<th>M</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>END SC308</td>
<td>PERS24</td>
<td>29.96</td>
<td>4.61</td>
<td>GEN24</td>
<td>31.8</td>
<td>3.57</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>2nd Year Practical Teaching Experience and Summer Break (6 months)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay Period 1</td>
<td>PERS25</td>
<td>30.03</td>
<td>3.79</td>
<td>GEN25</td>
<td>31.7</td>
<td>2.72</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>2012 - 1st Semester and 3rd Year Practical Teaching Experience (6 months)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay Period 2</td>
<td>PERS26</td>
<td>30.90</td>
<td>4.00</td>
<td>GEN26</td>
<td>31.1</td>
<td>3.04</td>
<td>42</td>
</tr>
</tbody>
</table>

A Leximancer analysis of the interviews conducted in 2012 showed some noteworthy themes. Figure 5 shows the relational themes that emerged within the coded transcript data. School Science Teaching was the most significant theme, encompassing their observations and experiences of school science on practical teaching placements. Unsurprisingly, Students and Personal Science Teaching themes were related to the school teaching context. The connective concepts between the themes show profound professional development amongst the interviewees. The School Science Teaching theme is underpinned by negative concepts noting the negative aspects of the science they observed. Time and Tried are the concepts at the intersection with the Personal Science Teaching theme. This suggests that the interviewees viewed their science teaching practice as both separate and more desirable than the observed science teaching practice.
While the interviewees displayed positive attitudes towards their own science teaching practices, in most cases they were either critical of, or unable to identify, science teaching in their school contexts. A total of 45 members of the cohort were surveyed after their practical teaching experiences. Approximately three quarters of the preservice teachers reported that they had taught science on their second year practical teaching experience. Curiously, less than half (48%) reported seeing science being taught. Whether or not the interviewees were aware, deeper analysis reveals that they may have been socialised into a culture of science marginalisation. In one short response, Bec cited a plethora of reasons for dismissing science despite addressing it in her own curriculum:
Definitely. Just all the setting up. Planning was a bit more difficult too and having to get your resources for it. I had to get everything. That’s also money from me, although I’m sure the school would have been happy to [pay]. With English and Maths you’ve got to cover so much and you want to get it ticked off before you start science. It is time consuming. Especially when you could just do an art lesson, like everyone does.

Conversely, another interviewee was highly critical of the science she observed during the placement. She chose to avoid common marginalisation processes as she made informed pedagogical and content decisions to deliver appropriate science lessons. Fiona said:

The content I taught was not as scientific as I had hoped. My associate teacher was very restrictive about what was to be taught. She just gave us a black and white printed off booklet and told us to teach it as she would which is basically colouring in the pictures in the book. My paired prac partner and I changed the book around and only kept some pages to group the content together and instead conducted experiments and SmartBoard activities that were meaningful rather than simply giving them sheets to colour in. The content we were originally given did not fit the Kindergarten syllabus at all so our activities steered the content so that it could actually satisfy the outcomes.

2013 – Final Year

The preservice primary teachers did not receive any formal science education during their final year of study (2013). STEBI-B data were collected during this period to assess the durability of the preservice teachers’ efficacy beliefs two years after the completion of their tertiary science learning. In their final semester, preservice teachers completed eight subjects and a final teaching internship during 2013. The teaching internship consisted of a 10 week practical placement where, for the first five weeks with reduced support, the preservice teachers were required to assume the responsibilities of a graduate teacher. For the final five weeks of the internship, the preservice teachers
taught without the direct supervision of an associate teacher. During this year, data were collected immediately prior to and immediately after the completion of the internship period (three months).

Not only did the preservice teachers’ science teaching efficacy beliefs remain durable, the mean STEB scores increased despite the absence of any science intervention for the intervening two year period. Table 7 shows the descriptive statistics for the STEB data collected at the end of 2012, pre internship 2013 and post internship 2013. The preservice teachers’ personal science teaching efficacy showed a small increase during their final year of study (Cohen’s d = 0.26). The cohort’s science teaching outcome expectancy beliefs showed a slightly greater increase (Cohen’s d = 0.41).

<table>
<thead>
<tr>
<th>Occasion</th>
<th>PSTE Occasion</th>
<th>M</th>
<th>SD</th>
<th>STOE Occasion</th>
<th>M</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Semester 2012</td>
<td><strong>PERS26</strong></td>
<td>30.90</td>
<td>4.00</td>
<td><strong>GEN26</strong></td>
<td>31.1</td>
<td>3.04</td>
<td>42</td>
</tr>
<tr>
<td>2012 Summer Break and 1st Semester 2013 (6 months)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Internship 2013</td>
<td><strong>PERS27</strong></td>
<td>31.13</td>
<td>4.67</td>
<td><strong>GEN27</strong></td>
<td>33.06</td>
<td>3.01</td>
<td>48</td>
</tr>
<tr>
<td>2013 Teaching Internship (3 months)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Internship 2013</td>
<td><strong>PERS28</strong></td>
<td>32.02</td>
<td>4.60</td>
<td><strong>GEN28</strong></td>
<td>32.57</td>
<td>4.03</td>
<td>55</td>
</tr>
</tbody>
</table>

A MANOVA with repeated measure was computed on the STEB data collected during the preservice teachers’ final year of tertiary studies. Table 8 presents the results from the MANOVA for this period. There was a significant effect on participants’ STEBs due to occasion of testing (F(1.68,53.83)=8.165, p = .001). This indicates that the growth in both the PSTE and STOE scores of the participants was statistically significant. An intriguing finding was that there was no significant difference between the PSTE and STOE subscales (F(1,32)=1.55, p = .222). This was the first time during the four year data collection period where the preservice teachers’ PSTE beliefs were not significantly lower than their STOE beliefs. One
interpretation of these results may be that their tertiary education had helped them to feel that they can meet their high standards for science teaching in general.

Table 8 MANOVA Output for the Final Year of Study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occasion</td>
<td>152.19</td>
<td>1.68</td>
<td>90.47</td>
<td>8.17</td>
<td>.001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>596.48</td>
<td>53.83</td>
<td>11.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEB</td>
<td>23.35</td>
<td>1.00</td>
<td>23.35</td>
<td>1.55</td>
<td>.222</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>481.65</td>
<td>32.00</td>
<td>15.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>21.28</td>
<td>2</td>
<td>10.64</td>
<td>3.39</td>
<td>.040</td>
</tr>
<tr>
<td>Error(Occasion*Variable)</td>
<td>200.72</td>
<td>64</td>
<td>3.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Summary of Results**

These data suggest that participation within the two science subjects (SC108 and SC308) covaried with statistically significant increases in both the PSTE and STOE scores for the cohort of preservice primary teachers. These improved science teaching efficacy beliefs remained durable after, and even increased in the absence of, the science subjects.

Figure 6 shows the STEB progression over the four year period, based on the mean scores for data provided at each occasion. The solid vertical lines represent the beginning of an academic year and the dotted lines represent the end of an academic year. Throughout the first two years of the degree, where the science subjects are situated in the course structure, the outcome expectancies of the preservice teachers are consistently higher than their personal science teaching efficacy beliefs. This trend appears logical as during these early stages, they possessed neither the experience, knowledge and skills of qualified teachers nor a real context within which they could observe teaching impacts. It should be noted that this difference between the STOE and PSTE scores is relatively unique in the literature as many researchers consistently report both higher scores and higher growth on the
PSTE subscale (e.g., Ford, Fifield, Madsen & Qian, 2012; Logerwell, 2009; Palmer, 2006). Another noteworthy trend was the continued increase in science teaching efficacy belief scores after the completion of the science subjects. The gap between the PSTE and STOE scores also decreased, indicating that the preservice teachers now felt confident that they could deliver quality science teaching on a par with the broader science teaching profession.

![Progression of STEB Scores over the Four Year Period](image)

**Figure 6** Progression of STEB Scores over the Four Year Period

To gain a holistic overview of the combined influence of both the science subjects (SC108 and SC308) and the other aspects of the teaching degree on the cohort’s STEBs a MANOVA was computed on the STEB data collected at the beginning of the degree (SC108 entry) and at the end of the degree (post internship). Forty five preservice teachers provided valid STEBI-B data on both occasions. Table 9 shows that there was a significant effect due to the STEB scales (F(1,44)=6.88, p=.012). The difference between the PSTE and STOE scales was more pronounced upon entry into the course and this reflected in the significant effect due to STEB by Occasion (F=(1,44)=6.88, p=0.12). There was a highly significant effect due to Occasion (F(1,44)=82.58, p<.0001). The PSTE and STOE subscales both showed large-to-very-large Cohen’s d effect sizes of 1.36 and 1.11 respectively.
### Table 9 MANOVA of STEB Data Collected on the First and Final Occasions of Testing over the Four Year Period

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occasion</td>
<td>1120.01</td>
<td>1</td>
<td>1120.01</td>
<td>82.58</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>596.74</td>
<td>44</td>
<td>12.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEB</td>
<td>81.34</td>
<td>1</td>
<td>81.34</td>
<td>6.88</td>
<td>.012</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>530.41</td>
<td>44</td>
<td>11.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>61.25</td>
<td>1</td>
<td>61.25</td>
<td>6.88</td>
<td>.012</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>391.5</td>
<td>44</td>
<td>8.90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Discussion

The research presented in this paper shows that participation in two complementary science subjects, comprising multiple innovative practices within a student centred design, covaries with improved science teaching efficacy beliefs and which are durable in the absence of treatment. Across both science subjects, participants displayed large effect size increases on both the PSTE (Cohen’s D = 0.75) and STOE (Cohen’s D = 1.08) subscales. Assessing both science subjects as a part of a broader science program may be the most suitable approach due to the statistically significant decline in STEB scores that occurred in the delay period between the first (SC108) and second (SC308) subject. After the cohort had completed the second science subject, their science teaching efficacy beliefs remained durable for two years without any formal science intervention. In fact, a pre- and post-course MANOVA showed large effect size increases in the PSTE (Cohen’s D=1.36) and STOE (Cohen’s D = 1.11). It appears the preservice teachers maintained their beliefs about the efficacy of science teaching whilst developing their personal science teaching efficacy beliefs through continued teaching experience and study.

Such findings indicate that the science subjects may be instilling in the participants the knowledge and skills necessary to overcome the culture
of science marginalisation that often exists within primary schools (e.g., Goodrum & Rennie, 2007; Griffith & Scharmann, 2008). Cross triangulation with other data sources appears to support this interpretation. After their practical teaching experience in second year, only 47% of the cohort reported seeing science taught within their school. Despite this finding, 74% of the preservice teachers reported teaching science themselves. While the participants’ resolve to teach science is promising, follow up research is needed to determine if the improved science teaching efficacy is accompanied by competent science teaching as the cohort enters the profession.

The weekly collection of data within the science subjects allowed for some insights into how different pedagogical innovations affected the science teaching efficacy beliefs of the preservice teachers. The embedded practical science teaching experience in the second science subject (SC308) covaried with the largest rise in PSTE scores within the data set. In a single week, the participants displayed a small, but significant, increase (Cohen’s d = 0.25) in their personal science teaching efficacy score. Many researchers report on the benefits of including practical teaching experiences within tertiary science subjects (e.g., Bautista, 2011; Lewthwaite, Murray & Hechter, 2012; Palmer, 2006; Velthuis, Fisser & Pieters, 2014). The findings in this research represent a substantial advancement in this area of research as the STEBI-B administrations allowed for the practical teaching event to be isolated from other components of the SC308 subject. This research provides reasonable evidence for the benefits of the inclusion of practical science teaching experiences in tertiary science education subjects. Nonetheless, more research is needed to strengthen such an argument. The benefits of practical science teaching experience could also open avenues for partnerships
between universities and schools where such opportunities could serve to counteract any negative science socialisation that appears to occur for both preservice and early career teachers in schools. Some research has been conducted on linking tertiary science subjects to extended professional experience placement (e.g., Bautista, 2011; Leonard, Barnes-Johnson, Dantely & Kimber, 2011; McDonnough & Matkins, 2010), but further research needs to be conducted in this potentially rich domain.

The interview data collected within this research serves to highlight the negative science socialisation that occurs within some primary schools. Such themes certainly fit with the negative trends that emerge within the wider literature base. Primary science is often marginalised (e.g., Appleton & Kindt, 2002; Appleton, 2003; Angus et al., 2004) and distorted (e.g., Goodrum & Rennie, 2007) by teachers who lack confidence in their capacity to teach science effectively (e.g., Palmer, 2011; Tytler, Smith, Grover & Brown, 1999). All of the interviewees noted the absence of science, but their interpretations of the science avoidance differed in two distinct ways. Some of the interviewees were highly critical of science marginalisation and chose to eschew the power structure that existed between themselves and their associate teachers by teaching science in a student centred way. Others seemed compelled to accompany their answers with rationalisations on behalf of their associate teachers. Issues such as time, resourcing and the crowded curriculum became key themes for the preservice teachers despite their own lack of experience within the teaching profession. Limited research exists that directly reports on science cultures at the primary level, but dissonance exists in larger science studies that hints at the negative science cultures. For example, teachers who participated in a national study into the state of science
education reported using student centred approaches, yet the primary students reported transmissive, teacher centred pedagogies (e.g., Goodrum, Hacking & Rennie, 2001). In the same report, many primary teachers cited the lack of professional development opportunities in science teaching. Yet, in a follow up study, many primary teachers displayed a lack of interest in engaging with professional development opportunities (e.g., Goodrum & Rennie, 2007). Given that any science gains made at the tertiary level will inevitably interact with the school cultures into which participants enter, research needs to be conducted to study science socialisation at the primary level.

Throughout the four year research period, the STOE scores of the participants were consistently higher than their PSTE scores for most of the time. It is logical that inexperienced preservice teachers would feel less efficacious in their own science teaching capacity than the capacity of science teaching to assist student learning in a general sense. Nonetheless, the overwhelming majority of the STEBI-B literature reports higher scores and growth on the PSTE subscale (e.g., Ford, Fifield, Madsen & Qian, 2012; Logerwell, 2009; Palmer, 2006). It is impossible to attribute this trend to any single factor within our science program or indeed within the four year data collection period. It could be posited that the alternative conception targeting that occurred early in SC108 made our students more acutely aware of the limitations of their science content knowledge. Additionally, the student centred, micro teaching environment showed them that teaching science requires a wide array of professional skills which they, as first year preservice teachers, did not yet possess. Such an interpretation is supported by the reduction in the gap between the scales that occurred as the cohort progressed through their degree. By the time that the group was ready to graduate, there
was no longer a statistically significant gap between their PSTE and STOE scores. This hints at a powerful narrative, wherein the cohort believed that their tertiary experiences had prepared them to meet their own expectations of primary science teaching. Nonetheless, follow up is research is needed to determine the validity of this interpretation.

The validity and reliability of the STOE subscale remains a point of contention within the STEBI-B literature (e.g., McDonnough & Matkins, 2010; Mullholland, Dorman & Odgers, 2004). As noted earlier, the STOE is often marred by low reliability scores (e.g., Aydin & Boz, 2010; Velthuis, Fisser & Pieters, 2014) or even dismissed or not reported. The current research afforded an opportunity to explore the reliability of the STOE subscale in a longitudinal manner. As the targeted cohort of preservice primary teachers progressed through their degrees, the reliability of their responses to the STOE items increased. At the beginning of the first year, the STOE was reported to have a Cronbach’s alpha of 0.687, by the end of the second year this had increased to 0.798. Most notably, despite no formal science intervention during the interim period, the STOE Cronbach’s alpha had increased to 0.87 and at the end of the fourth year, was very close the 0.88 reliability score of the PSTE subscale. These reliability scores represent one of the only times in the literature where both the PSTE and STOE subscales display equal reliability. This reaffirms the importance of practical teaching experiences both within and beyond tertiary science programs. There is some evidence here to suggest that the STOE reliability increases naturally over the course of a tertiary teacher education program, as preservice teachers’ develop deeper understandings of the teaching profession. While the aforementioned STOE issues are valid, they are not infallible nor do they
remove the imperative to improve preservice primary teachers’ beliefs about the capacity of science teaching to guide students to desired learning outcomes. Simply put, researchers must continue to improve preservice teachers’ science teaching outcome expectancies.

There are several implications for further research that have been revealed by the research outlined in this paper some of which have been discussed. Follow up research is needed to explore the science teaching efficacy beliefs and science teaching practices of the preservice primary teaching cohorts as they begin their teaching careers. A disconnect exists between tertiary and primary school contexts as research seldom bridges this gap (e.g., McKinnon & Lamberts, 2014). It is necessary to extend research beyond the tertiary context if the goal of improving students’ scientific literacy is to be addressed. Research also needs to be conducted explicitly on the negative science cultures that appear to exist in primary schools. Such research would provide insights into the types of interventions required to overcome the issues of science avoidance and marginalisation. From a methodological standpoint, more research needs to adopt multiple cohort designs, longitudinal approaches and good quasi experimental designs. This would improve arguments for covariance amongst variables and potentially establish causal links between science interventions and outcomes.
References


Connective Statement Three

The previous paper entitled “A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers” (Deehan, Danaia & McKinnon, 2016) studied the science teaching efficacy beliefs and science teaching perspectives of a cohort of preservice primary teachers over a four-year period where they completed two complex, innovative science courses (SC108 and SC308). The research employed two Type II, quasi-experimental case studies with additional delayed data collection periods. Data were collected through mixed methods, including the STEBI-B (see appendix 4, p.387), semi-structured interviews, Harvard one minute papers and course evaluations. The paper investigated the participants’ experiences and science teaching efficacy beliefs within, across and beyond the two science courses. In total, 112 members of the cohort provided quantitative STEBI-B data on at least one occasion of testing, with 56 providing data on the final occasion. A group of 12 preservice teachers contributed additional interview data. In their first year of study, the cohort reported improved personal science teaching efficacy beliefs (Cohen’s $d = 0.41$), science teaching outcome expectancies (Cohen’s $d = 0.79$) and science teaching confidence as they completed the SC108 course. There was an unexplained decline in their science teaching outcome expectancies (Cohen’s $d = -0.56$) during the year between the completion of SC108 and the start of SC308. However, upon completion of the project-based SC308 course the STOE declines were reversed (Cohen’s $d = 0.65$). In addition, participants continued to show improved PSTE scores (Cohen’s $d = 0.69$) with the largest single week increase occurring immediately after an in-course practical science teaching experience. Over the final two years of the cohort’s formal
tertiary studies, their personal science teaching efficacy beliefs continued to increase while their science teaching outcome expectancies remained durable. There is strong evidence to suggest that participation in the science program, as described in the second publication, covaries with large and durable increases to science teaching efficacy beliefs. The next step is to supplement this deeper mixed methods research with broader quantitative research to both strengthen the aforementioned argument for covariance and to consolidate the position of the science program within the STEBI-B literature.

The next publication reports on extensive STEBI-B (see appendix 4, p.387) data extracted from multiple SC108 and SC308 course offerings over an eight-year period. The vast sample size presented in the next quantitative publication is the broad accompaniment to the deep, mixed methods research presented in the previous publication. By reporting on the science teaching efficacy beliefs of large sample of SC108 and SC308 participants over nearly the course of a decade, the argument for covariance can be strengthened in a way that is nearly unprecedented within the body of STEBI-B literature. Aside from the enhanced generalisability afforded by the large sample size, the next publication allows for additional aspects (e.g., instructor variations) to be explored indirectly through investigation of STEB changes within and between cohort groups.

The next publication entitled “A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers” (Deehan, McKinnon & Danaia, 2016) reports on multiple quasi-experimental, type II case studies with pre- and post-test administrations of the STEBI-B during iterations of the SC108 and SC308 course offered from 2007 through to 2014. There were 877 preservice teachers who responded to the STEBI-B
in full on at least one occasion over the 8-year period of data collection. A series of Multivariate Analysis of Variance (MANOVA) tests with repeated measures on the occasion of testing have been computed to determine if the PSTE and STOE scores of participants changed significantly both within and across the SC108 and SC308 courses. All cohorts, bar two (2009 SC108 and 2014 SC308) showed highly significant STEB increases over the duration of the courses. In terms of science teaching efficacy growth, the SC108 and SC308 courses were complementary as SC108 covaried with greater STOE growth whereas SC308 participants showed larger PSTE increases. The statistical analyses to be presented in the next publication appear to reflect the findings shown in the third publication. The consistently high STOE scores, the STOE growth and the teacher variable are key discussion points in the next publication.
Publication Four

A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers

Publication four has been submitted to the Journal of Research in Science Teaching (see appendix 9, p.400). Language and formatting have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Research Conceptualisation
- Data Collection (2013-2014)
- Data Analysis (All years)
- Manuscript Drafting
- Manuscript Editing
A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers

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Author Note
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Abstract

If the steady decline in science interest and performance permeating all levels of science education in Australia is to be reversed, it is imperative that competent and confident teachers deliver quality science experiences. This paper reports on the long-term implementation of two complementary, innovative tertiary science courses that were designed to develop both the competence and confidence of preservice primary teachers at a rural Australian university. The Science Teaching Efficacy Belief Instrument B (STEBI-B) was employed to collect data from multiple cohorts of preservice primary teachers (2007-2014) in two separate science courses that integrated instruction in science content with science teaching methods. Multiple iterations of a longitudinal quasi–experimental design replicated in each course and in each year were employed to investigate any changes. Data were analysed using MANOVA with repeated measures on the occasion of testing across the two science courses. Participants were 877 preservice teachers over eight years. Results indicate that both preservice teachers’ personal and outcome efficacy beliefs grew significantly with moderate to large effect sizes (Cohen’s d). The combined effect of the two courses is also reported. The significantly higher outcome efficacy beliefs and comparable growth in the personal efficacy domain of the STEBI-B are atypical within the wider literature. Broader implications are discussed within the paper.

Keywords: Teacher education – prospective teachers, science teaching efficacy beliefs, teacher beliefs, quantitative, longitudinal research
A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers

Introduction

There is considerable variation among the course structures and pedagogical practices of science-methods courses within primary preservice teacher education courses in Australian universities. Lawrance and Palmer (2003) reviewed a variety of pedagogical and science–curriculum innovations that were being implemented in tertiary education institutions to develop quality primary school teachers who would also teach science as part of their general role. Representatives from 35 teacher education institutions participated in open-ended telephone interviews where they described their science teaching programs. The most prominent innovative themes mentioned by 60% of the respondents involved collaboration with the science faculty and the integration of information and communications technologies (ICTs). Some institutions reported incorporating at most one or two of the following: explicit Pedagogical Content Knowledge (PCK) instruction (Nillson & Loughran, 2011); student choice; community links; and, hands-on practical experiences. A small number of institutions indicated a use of Problem–based Learning approaches. One would anticipate that such variety amongst university teaching approaches would lead to a wide variance in graduate teaching standards.

None of the above innovations identify inquiry-based learning approaches overtly. It might be inferred that the use of problem-solving approaches coupled with hands-on practical experiences may involve aspects of inquiry learning. Many preservice science interventions involve inquiry-based learning strategies (Luera & Otto, 2005). However, even though
inquiry is prominent within the literature, it remains an ill-defined construct for many educators (Abrams, Soutterland & Evans, 2008; Settlage, 2007). This can leave teachers with the task of deciphering the meaning of “inquiry” within their own classroom contexts (Crawford, 2000; Keys & Bryan, 2000; Saka, Southerland & Golden, 2009; Wu & Krajcik, 2006).

In essence, inquiry allows students to assume agency over the purpose and direction of their own learning (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; Roth, 1995). Inquiry learning allows participants to develop transferable skills and knowledge to seek the information needed in order to achieve a goal that they have outlined (Duran, Ballone-Duran, Hancy & Belyukova, 2009; Edelson, Gordin & Pea 1999). In such a classroom, teachers subsequently take on facilitative and supportive roles ranging from the structured processes of guided inquiry to the open-ended learning promoted by open inquiry.

Sackes et al. (2012) found that inquiry-based approaches could be used to develop deep learning in both mathematics and science. Moreover, the inclusion of inquiry-based pedagogies and reflective practices in multiple science content courses can coincide with significant improvements in both the science-teaching efficacy and the science content knowledge of preservice teachers (Luera & Otto, 2005). Learning based on inquiry is thus an approach that represents a true separation from teacher-centred approaches wherein students can make informed choices about their own learning pathways. However, Lawrance and Palmer (2003) noted barriers to the implementation of such student-centred approaches in preservice science teacher education. One such barrier is the increasing number of casual academics or adjunct professors recruited from schools who are employed to teach the science
methods courses to preservice teachers. Tenured professors in universities believed that many of these former practicing teachers preferred transmissive approaches. Lawrance and Palmer (2003) noted that this was a problematic situation given that these transmissive approaches were one of the factors that alienated students.

Problem-Based Learning (PBL) is a deep–learning strategy that helps students to develop transferrable skills that can be used in novel situations (Schmidt, Saigo & Stepans, 2006). PBL uses real–world problems as a starting point for the acquisition and integration of new knowledge into existing schemas (Azer, 2001; Kahn & O’Rourke, 2005). In the tertiary sphere, PBL often incorporates curriculum development to model the demands and changing nature of the teaching profession. In his review into science teacher education, Lawrance and Palmer (2003) found that only a small number of institutions used a PBL approach for either the science methods or the content courses. However, those institutions who did employ PBL reported very positive outcomes for participants. Ford et al. (2012) collected interview data from 159 preservice teachers over a two–year period. The results indicated that participants in a PBL program developed a more sophisticated pedagogical understanding of science teaching as they moved beyond the overly simplistic notions of the ‘hands–on activities that work’, which are frequently reported in the literature (Appleton, 2003; Appleton & Kindt, 2002; Ertmer, Schlosser, Clase & Adedokun, 2014). Upon completion of the course, the preservice teachers discussed both ‘inquiry’ and ‘investigation’ in science teaching as these related to the processes of scientific investigation, which suggests a more sophisticated, although still developing, understanding of science pedagogies. In the development and
implementation of a PBL tertiary science program, Watters (2007) found a curious disconnect between preservice teachers’ attitudes towards PBL learning and the outcomes achieved within the courses. Despite improved pedagogical capacity and science teaching confidence, many respondents bemoaned the complex requirements and group–based nature of the tasks.

While the benefits of PBL have been established within the literature (Ford, Allen, Dagher & Donham, 2011; Huinker & Madison, 1997; Logerwell, 2009; Watters & Ginns, 1999), it is a deep and complex pedagogical approach that requires scaffolding and support structures to be present for the preservice teachers. The nature of the ideal scaffolds and support structures remains relatively unclear. In order to facilitate effective PBL environments, cooperative learning strategies must be explicitly modelled and supported.

Cooperative learning is an educational construct wherein a group of students work together to develop their knowledge and skills through the achievement of a clearly defined goal. Learning is supported through the principles of social constructivism that have underpinned educational theory for decades (Ruys, Van Keer & Aelterman, 2010; Santrock, 2007; Vygotsky, 1977). According to Blosser (1993) participants need to make meaningful contributions to a task that cannot be achieved by a single individual. Thus, participants need to develop and use interpersonal and reflective skills. Palmer (2006) used cooperative learning as a key component of his science methods course targeting second year preservice primary teachers. The results showed significant increases in both the personal and outcome science teaching efficacy beliefs of the participants that were durable for up to a year after the completion of the course.
Practical science teaching experiences in real classroom settings are essential for improved science attitudes and teaching practices (Bhattacharyya, Volk & Lumpe, 2009; Ebrahim, 2012; Palmer, 2011; Wingfield & Ramsey, 2001). Palmer (2007) noted that several institutions had successfully embedded practical science teaching experiences within their science courses and that one institution had conducted workshops in actual school settings. Research has shown that participation in a site–based methods course covaries with both improved science teaching efficacy beliefs and more positive attitudes towards science for preservice teachers (Wingfield & Ramsey, 2001). The data collected from 131 preservice teachers showed significant increases in both personal and outcome science teaching efficacy beliefs. The participants themselves attributed these changes to the embedded opportunities for science teaching practice within the course structure. Palmer (2011) further found that ‘enactive mastery’ is a vital component in the consolidation of improved personal science teaching efficacy for preservice primary teachers.

It is important to note, however, that practical science teaching experience does not supplant the need for formal tertiary education involving analysis of pedagogical approaches. Indeed, Ebrahim (2012) found that a practical teaching science experience, without supplementary instruction, produced no discernible changes in the participants, whereas those in a science methods course did make significant knowledge and attitudinal gains. This suggests that practical experiences need to be linked to a broader course structure in order to maximise the educational value. Bhattacharyya, Volk and Lumpe (2009) established the value of incorporating practical teaching experiences within an inquiry-based science course. In this study, the
preservice teachers needed to establish their fundamental capacity to communicate with school students prior to adopting different instructional strategies.

While there is clearly a plethora of worthwhile approaches for tertiary science courses, it is difficult to assess such approaches in isolation. Haeusler and Lozanovski (2010) designed a preservice primary science course for both face–to–face and distance modes of education that included elements of inquiry, cooperative learning and PBL. Preservice teachers who experienced both modes of delivery showed significant growth in their personal science-teaching efficacy. Additionally, the participants believed that the use of cooperative learning enhanced their science learning in comparison to their previous tertiary experiences. Huinker and Madison (1997) reported on a similarly deep science methods course that included links to mathematics, targeting alternative conceptions, and inquiry based learning. Participants showed improved personal science teaching efficacy and developed deeper understandings on the nature of scientific investigation.

Research Aims and Question

Given the trends within the science education literature, this paper reports on two similarly complex course designs and investigates the impact they have on preservice primary teachers’ science teaching efficacy beliefs. The research presented in this paper builds on the existing literature by reporting on data collected across multiple iterations of two interlinked science courses involving content and methods. The science courses represent a step forward in this domain as each is comprised of 11 interwoven innovative practices, which exceeds the number that is often reported. Thus, the research presented in this paper aims to provide some clarity in this area of science education by
presenting rich quantitative evidence for the use of an innovative and student-centered model of preservice primary science education. The two science courses are comprised of a variety of interwoven innovative practices that have already been established within the literature. Rather than simply determining what approaches should be used in tertiary education, the research also uses longitudinal quantitative data to argue that the two courses represent a viable, replicable model for how innovative practices can be used to enhance outcomes for preservice teachers. The designs of the two science courses are outlined later in the paper. The research aims for this paper are twofold, to report the changes in the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers (2007-2014) both within and across the separate science courses. The following question frames the research presented in this paper; does participation in two innovative, complementary science courses, both separately and collectively, covary with statistically significant increases to the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers?

**Theoretical Framework: Teacher Efficacy in Science Education**

Self-efficacy can be defined as one’s internal beliefs relating to his or her competence in completing a specific task (Bandura, 1977, 1986). Self-efficacy is widely considered to comprise two conceptually separate elements: Personal Efficacy (PE); and, Outcome Expectancy (OE). PE relates to an individual’s belief about his or her capacity to successfully complete a task. OE relates to an individual’s belief that the completion of the task will have the desired outcome. Both constructs are vital when considering an individual’s likelihood of persevering through adversity to complete a task. Many domains are affected by self-efficacy with teaching being one such
domain. Teacher Efficacy has been found to correlate positively with desirable outcomes in both teachers and students (Goddard, Hoy & Hoy, 2000; Tschannen-Moran & McMaster, 2009). Teacher efficacy is the confidence an individual has in themselves or their profession to help students to achieve pre-determined educational outcomes (Berman, McLaughlin, Bass, Pauly & Zellman, 1977). Teacher efficacy is comprised of two key aspects; these are Personal Teaching Efficacy (PTE) and General Teaching Efficacy (GTE). PTE describes an individual’s belief in their own ability to overcome contextually specific factors to promote student learning (Coladarci, 1992; Gordon & Debus, 2002). GTE is the belief that teaching in general can overcome external factors, such as socio-economic status, various learning needs and detrimental social experiences, to guide students towards achieving pre-determined goals (Tschannen-Moran & Hoy, 2001).

Riggs and Enochs (1990) designed two science teaching efficacy instruments that were modelled on the Teacher Self Efficacy scales (TSES) produced by Gibson and Dembo (1984). The Science Teaching Efficacy Belief Instrument A (STEBI-A) was designed to measure the science teaching efficacy of inservice primary teachers (Enoch & Riggs, 1990) while the Science Teaching Efficacy Belief Instrument B (STEBI-B) was designed to measure the science teaching efficacy of preservice primary teachers (Riggs & Enochs, 1990). These instruments are equivalent because the STEBI-B was designed by modifying the wording of items from the original STEBI-A to reflect the perspectives of preservice teachers. Both instruments measure two aspects of science teaching efficacy: Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). These are equivalent to the two more general scales identified by Gibson and Dembo
Moreover, preservice teachers with higher science teaching efficacy beliefs are more likely to: hold higher levels of science content knowledge (Mashnad, 2008; Sarikaya, Çakiroğlu & Tekkaya, 2004); report fewer alternative scientific conceptions (Schoon & Boone, 1998); and, also possess high mathematics teaching efficacy beliefs (Bursal & Paznokas, 2006).

**Context**

The context for this study is a Bachelor’s teaching degree offered by an Australian university where preservice teachers were required to undertake four years of tertiary study in primary curriculum and pedagogies to qualify them for employment in the educational jurisdiction. More specifically, this study focuses on the two compulsory science courses within the degree structure from 2007 through to 2014. The pedagogical approaches of the final offerings of both science courses are outlined in Table 1. It should be noted, however, that the courses evolved over time. The following subsections outline the structure of the science courses. For clarity, the descriptions are based on the final iterations of the courses.

**Table 1 Approaches used within the Two Science Courses**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Course 1</th>
<th>Course 2</th>
</tr>
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<tbody>
<tr>
<td>Constructivism</td>
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<tr>
<td>Problem-based Learning</td>
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<tr>
<td>Project-Based Learning</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Integration with other Key Learning Areas (KLAs)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Mentoring</td>
<td></td>
<td></td>
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<tr>
<td>Real world relevance</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Inquiry learning</td>
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<td>*</td>
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<tr>
<td>In-course practical experience</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Links to practical experience blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperative Learning</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>ICT Instruction</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Student Centred Investigation</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Rich Tasks</td>
<td></td>
<td></td>
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<tr>
<td>Nature of Science</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Misconception targeting</td>
<td>*</td>
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</tbody>
</table>
Course 1 - SC108: Science and Technology Studies I

The first science course used the Astronomy content relevant to the primary science curriculum as a driver for the development of preservice teachers’ science content knowledge and their Pedagogical Content Knowledge (PCK) (Nillson & Loughran, 2011). A Problem Based Learning environment was created by submitting the students to a modified ‘Astronomy Diagnostic Test’ (ADT) (CAER, 1999) in the first week of classes. The students were then required to identify and target their own alternative scientific conceptions and to address these in cooperative, micro–teaching groups. The micro–teaching approach was inquiry based as each preservice teacher was required to select the pedagogical approaches they employed to teach astronomy content to their peers and to reflect on their own teaching and that of their peers. Throughout the course, the professors acted as facilitators to help the participants to progress through the science learning experiences. In a scaffolded approach, the professors provided instruction, modelling and guidance on cooperative learning, instructional approaches, and research skills in a fashion that gradually allowed the students to assume the locus of control as their skills and knowledge developed. In a backward-faded scaffolding approach (Slater, Slater & Shaner, 2008), the preservice teachers reapplied their new science skills and knowledge to a firsthand scientific investigation of their choosing. This approach enhanced both their investigative skills and understandings of the nature of scientific investigation. Students’ knowledge outcomes in the learning of Astronomy content was assessed by post-test administration of a slightly modified version of the ADT in the final week of the semester. That is to say, success
in this post–test served to demonstrate to participants and professors that they were competent in having understood the science content knowledge.

**Course 2 - SC308: Science and Technology Curriculum Studies II**

The knowledge and skills developed in SC108 served as prerequisites for entry into the second SC308 course. SC308 moved beyond the Astronomy focus of SC108, as preservice teachers were required to develop further their Pedagogical Content Knowledge (PCK) (Magnusson, Krajcik & Borko, 2002; Van Driel & Berry, 2010) in order to teach other syllabus content effectively. A hybrid constructivist pedagogical approach was used within an extended role-play, project-based learning scenario where the professor acted as the principal of the school (that class) and the preservice teachers assumed the role of teachers within the school. The preservice teachers worked in cooperative learning groups throughout the semester (approximately 4 per group) to create a science unit of work for a pre-determined science content strand and a particular grade level. Each class had a different science content focus within which each cooperative learning group focussed on a different grade level. In their cooperative learning groups, the preservice teachers were required to navigate the syllabus, research science content and make pedagogical decisions to design and implement a teachable unit of work. A key learning inclusion was an in-school science teaching experience where the preservice teachers were required to teach their science lessons to small groups of primary students at the relevant grade level. The goal of this educational paradigm was to provide the preservice primary teachers with the skills and knowledge necessary to research and adapt science concepts for the classroom. Most importantly, the experience provided opportunities for them
to develop their science PCK in a manner that assisted them to feel more confident and competent to teach primary school science.

**Methodology**

This research employed a quasi-experimental design within a Type II case study framework (Merriman, 1998; Shadish, Cook & Campbell, 2002; Yin, 2014). A Type II Case study incorporates multiple forms of data collected from a single site. An experimental design with equivalent control groups could not be conducted ethically within the tertiary context. Therefore, this research explores covariant relationships amongst variables rather than establishing causality. The research can be deemed quasi-experimental as groups were not formed randomly. The treatments in this research project were the aforementioned SC108 and SC308 science courses. The science courses were complementary and sequential within the broader primary teaching course structure. This means that most ‘in-phase’ participants experienced both interventions with a delay period of one year between each. Therefore, a repeated–measures design has been employed to strengthen the argument for covariance between STEB changes and course participation (Shadish, Cook & Campbell, 2002). From a broader perspective, the research was longitudinal as STEBI data were collected from the same courses in each cohort year, over an eight-year period. This enabled the researchers to explore and evaluate the development of the science courses over time. Quantitative data were collected with multiple administrations of the STEBI-B instrument. Table 2 below outlines both the data collection occasions and the number of participants who supplied complete data sets on each occasion from 2007 to 2014.
Table 2 STEBI-B Data Collection Periods for SC108 and SC308 (2007-2014)

<table>
<thead>
<tr>
<th>Cohort</th>
<th>SC108 (Semester 1)</th>
<th>SC308 (Semester 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
</tr>
<tr>
<td>2007</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2008</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2009</td>
<td>✓</td>
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<tr>
<td>2010</td>
<td>✓</td>
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</tr>
<tr>
<td>2011</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2012</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2013</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2014</td>
<td>**</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* Data were not collected for the SC308 post-test in 2012
** SC108 did not run in 2014. It is no longer a part of the Degree with the content knowledge now being taught by Science Faculty and which will allow differing treatments to be investigated.

Participants

The participants in this research project were preservice primary teachers undertaking a Bachelor of Education (Primary) degree at an Australian rural university between 2007 and 2014. The age of the participants ranged from 18 to 55. While 877 individuals provided data on at least one occasion, only those who provided matched pre-post data in at least one course (SC108 or SC308) were included in the analyses. A total of 234 preservice teachers provided data on all four occasions of testing across both courses and were subsequently included in the science program analyses (both SC108 and SC308). Ethical clearance for the research presented within this paper was granted by the university’s Human Research Ethics Committee (2006/122).

The STEBI-B Instrument

The Science Teaching Efficacy Belief Instrument B (STEBI-B) was designed to measure the science teaching efficacy beliefs of preservice primary teachers (Enochs & Riggs, 1990). The instrument requires respondents to rate their level of agreement with statements on a 5-point Likert scale, ranging from ‘strongly disagree’ to ‘strongly agree’. The statements produce
measurements on two subscales. The Science Teaching Outcome Expectancy (STOE) belief scale measures the participants’ broad views of science teaching related to why school students perform as they do. An example of an item on the STOE subscale is “When a student does better than usual in science, it is often because the teacher exerted a little extra effort”. The Personal Science Teaching Efficacy (PSTE) scale measures the participants’ beliefs about their own ability to teach science effectively. An example of an item on the PSTE scale is “I know the steps necessary to teach science concepts effectively”. The items produce ordinal data as there are no observable or standardised intervals between the Likert responses of ‘strongly agree’, ‘agree’, ‘uncertain’, ‘disagree’, and ‘strongly disagree’ (Kervin Wilma, Herrington & Okely, 2006).

There are some issues with the use of the STEBI-B instrument in the literature. The STOE subscale is not as reliable as the PSTE (Aydin & Boz, 2010; Bleicher, 2006; Riggs & Enochs, 1990). Researchers often choose to omit the STOE subscale entirely due to its low reliability (Bursal, 2010). Cannon and Scharmann (1998) believe that preservice teachers lack the broad conceptual understanding of science teaching to respond consistently to the items in the STOE subscale. Others believe that the inherent complexity of the STOE diminishes its worth as a measure (Mulholland & Wallace, 2003). Although there are merits to these arguments, preservice teachers need to develop their STOE beliefs to cope with the negative contextual factors that currently exist in primary science education (Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007; Griffith & Scharmann, 2008). Therefore, the research presented in this paper utilises the STOE subscale and we present evidence that the STOE scale is reliable.
Enochs and Riggs (1990) reported Cronbach’s Alpha reliability coefficients of 0.90 for the PSTE subscale and 0.76 for the STOE subscale. Table 3 shows the Cronbach’s alpha reliability coefficients for the PSTE and STOE subscales on the four main occasions of testing across the science course offerings from 2007 through to 2014. The PSTE scale showed increased reliability through each occasion of testing. This may be related to the respondents’ growing base of science teaching experiences and knowledge as they progressed through their degrees. In this research, the STOE subscale does not show the low reliability that is widely reported in the literature (Baldwin, 2014; Velthuis, Fisser & Pieters, 2014). The STOE was found to be sufficiently reliable on all occasions.

Table 3 Cronbach’s Alphas for the STEBI-B Subscales

<table>
<thead>
<tr>
<th>Scale</th>
<th>PSTE Pre Occasion</th>
<th>PSTE Post Occasion</th>
<th>STOE Pre Occasion</th>
<th>STOE Post Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>α</td>
<td>n</td>
<td>α</td>
<td>n</td>
</tr>
<tr>
<td>SC108</td>
<td>0.760</td>
<td>733</td>
<td>0.858</td>
<td>563</td>
</tr>
<tr>
<td></td>
<td>0.810</td>
<td>568</td>
<td>0.787</td>
<td>528</td>
</tr>
<tr>
<td>SC308</td>
<td>0.820</td>
<td>489</td>
<td>0.887</td>
<td>527</td>
</tr>
<tr>
<td></td>
<td>0.797</td>
<td>528</td>
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</tbody>
</table>

Another issue within the STEBI-B literature is the overuse of designs featuring a single cohort with pre/post-test administrations of the instrument (Brower, 2012; Bursal, 2008; Christol & Adams, 2006; Jabot, 2002). Consequently, the use of multiple cohorts can strengthen interpretations made about covariant relationships between interventions and STEB increases. The eight-year period over which data were collected and reported in this paper is currently unparalleled within the body of STEBI-B literature.

Data Analyses

For the STEBI-B data, Multivariate Analysis of Variance (MANOVA) with repeated measures on the occasion of testing were computed to determine if the PSTE and STOE scores of participants changed significantly both within
and across the SC108 and SC308 courses (Coleman & Pilford, 2008). Cohen’s d effect sizes were computed to determine the impact of any STEB changes that were found to be statistically significant. The Statistical Package for the Social Sciences (SPSS) v20 software was used to analyse and produce descriptive statistics, tests for the homogeneity of variance and tests for the equality of the covariance matrices to ensure that the mathematical assumptions of the statistical procedures were met.

The homogeneity of variance statistics for the two STEB subscales over the four occasions of testing using cohort groups as the independent variable of were investigated using Box’s Test of Equality of Covariance Matrices. The null hypothesis of equality of the covariance matrices had to be rejected. An omnibus MANOVA was not computed because of the variety of complex mathematical transformations that were required to render each dependent variable on each occasion of testing individually and collectively normally distributed. Thus, the use of the cohort year as an independent variable had to be abandoned due to differences in the distributions of the subscales over time. To address this issue, separate cohort analyses were computed in order to meet the mathematical assumptions of the MANOVA procedure.

The researchers recognise that computing multiple MANOVA analyses for each cohort year artificially increases the likelihood of finding significant relationships between variables. A full Bonferroni correction was employed for the analyses to reduce the risk of a Type I error occurring, viz., claiming a difference when none might exist. The accepted p-value (< 0.05), adopted leading to the rejection of the null hypothesis of no difference was
divided by the number of MANOVA analyses computed to reduce the chance of a Type I Error.

Results

The results of this research are presented in three sections. First, the results from the SC108 course are presented. Second, the STEB analyses for those who completed the SC308 course are shown. Finally, the combined effects of both science courses (SC108 and SC308) are assessed through the analysis of STEB data provided by individuals across all four occasions of testing.

SC108 Results

In the tables that follow, the data are presented by the year of the SC108 course offering. A similar structure is employed for the SC308 results to follow. For the combined analyses presented in the science program results section a two-year cohort naming structure is used. Table 4 presents the MANOVA with repeated measures on the occasion of testing for the STEB data collected in SC108 from 2007 through to 2013. There is a significant main effect due the variables, PSTE versus STOE, (F(1,533)=180.21, p < 0.0001). That is to say, there is a significant difference between the Personal Science Teaching Efficacy and Science Teaching Outcome Expectancy beliefs of the SC108 participants. There is a significant within-group main effect due to the occasion of testing (F(1,533)=246.73, p < 0.0001). This shows that there is a significant increase in both of the STEB variables due to the occasion of testing of the preservice teachers who participated in the SC108 course.
Separate MANOVAs were computed on the STEBI-B data collected for each the SC108 course offerings from 2007 through to 2013 to address the issues with the lack of equality of homogeneity in the covariance matrices for the year groups and a significant Box’s M statistic. The 2007, 2008, 2010, 2011, 2012 and 2013 SC108 year groups all showed highly significant main effects due to the occasions of testing. The 2009 SC108 year group did not show a statistically significant change in their STEBs due to the occasion of testing (F(1,71)=5.786, p=0.19). In total, 86% of the SC108 cohorts showed statistically significant growth in their STEB scores. That is to say, the majority of preservice teachers showed improved science teaching efficacy beliefs upon completion of the SC108 course.

Participants in SC108 showed increased personal science teaching efficacy beliefs. Table 5 shows the descriptive statistics for the PSTE and STOE scores in SC108. There has been a steady, if inconsistent, raise in the PSTE effect sizes produced since 2007. Moderate gains were consistent after 2010, with a large effect size produced in 2012. Data from 2007 and 2009 represent outlying cases where there were no significant changes in the personal science teaching efficacy beliefs of the participants. The improvements could be related to reflection and subsequent course alterations made after each offering of the SC108 course. Regardless, the cumulative

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>3734.38</td>
<td>1</td>
<td>3734.38</td>
<td>180.21</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Variable)</td>
<td>11003.37</td>
<td>533</td>
<td>20.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>2795.45</td>
<td>1</td>
<td>2795.45</td>
<td>246.73</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>6016.30</td>
<td>533</td>
<td>11.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * Variable</td>
<td>35.02</td>
<td>1</td>
<td>35.02</td>
<td>4.16</td>
<td>0.008</td>
</tr>
<tr>
<td>Error(Occasion * Variable)</td>
<td>4470.73</td>
<td>533</td>
<td>8.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
mean effect size of 0.45 is slightly more than half of the mean (0.83) reported in the wider body of STEBI-B literature (Deehan, 2016).

Within the SC108 course, preservice teachers have consistently displayed moderate to large effect size increases in their science teaching outcome expectancies. Unlike the PSTE scores, there are no significant outliers or emergent trends for the STOE subscale. This is particularly noteworthy given the aforementioned issues with the STOE subscale and the variance reported in the PSTE scores within the SC108 course offerings. The mean 0.70 STOE effect size for the entire group is higher than the mean of 0.43 reported within the STEBI-B literature (Deehan, 2016). All cohorts produced moderate to large STOE effect sizes above the literature mean. This is the inverse of the PSTE trends, where only the 2012 SC108 cohort scored above the literature mean.

**SC308 Results**

A MANOVA was computed using the SC308 STEBI-B data to investigate changes to their science teaching efficacy beliefs. The summary output of the MANOVA analysis is displayed in Table 6. For those who

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Table 5 SC108 – PSTE and STOE Descriptive Statistics with Effect Sizes

<table>
<thead>
<tr>
<th>Year</th>
<th>PSTE</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Pre Occasion</th>
<th>Post Occasion</th>
<th>Sig.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Pre Occasion</th>
<th>Post Occasion</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>26.15</td>
<td>4.46</td>
<td>26.79</td>
<td>4.85</td>
<td>0.14**</td>
<td>27.63</td>
<td>3.77</td>
<td>30.26</td>
<td>3.84</td>
<td>0.69***</td>
<td>99</td>
</tr>
<tr>
<td>2008</td>
<td>26.12</td>
<td>4.41</td>
<td>29.15</td>
<td>4.42</td>
<td>0.69***</td>
<td>27.48</td>
<td>3.38</td>
<td>30.45</td>
<td>3.43</td>
<td>0.87***</td>
<td>95</td>
</tr>
<tr>
<td>2009</td>
<td>27.65</td>
<td>4.55</td>
<td>27.76</td>
<td>4.80</td>
<td>0.02 ns</td>
<td>29.13</td>
<td>3.27</td>
<td>30.94</td>
<td>3.56</td>
<td>0.53**</td>
<td>72</td>
</tr>
<tr>
<td>2010</td>
<td>26.09</td>
<td>4.11</td>
<td>28.39</td>
<td>5.77</td>
<td>0.46**</td>
<td>28.51</td>
<td>3.48</td>
<td>31.32</td>
<td>3.47</td>
<td>0.81***</td>
<td>108</td>
</tr>
<tr>
<td>2011</td>
<td>25.93</td>
<td>3.50</td>
<td>28.95</td>
<td>6.23</td>
<td>0.60***</td>
<td>29.95</td>
<td>2.91</td>
<td>31.95</td>
<td>3.61</td>
<td>0.61**</td>
<td>40</td>
</tr>
<tr>
<td>2012</td>
<td>26.06</td>
<td>3.56</td>
<td>29.22</td>
<td>3.76</td>
<td>0.86***</td>
<td>29.66</td>
<td>3.63</td>
<td>31.81</td>
<td>3.77</td>
<td>0.58**</td>
<td>73</td>
</tr>
<tr>
<td>2013</td>
<td>25.02</td>
<td>3.35</td>
<td>27.51</td>
<td>4.43</td>
<td>0.63***</td>
<td>29.98</td>
<td>2.97</td>
<td>32.85</td>
<td>3.40</td>
<td>0.90***</td>
<td>47</td>
</tr>
<tr>
<td>All</td>
<td>26.24</td>
<td>4.13</td>
<td>28.28</td>
<td>4.94</td>
<td>0.45**</td>
<td>28.64</td>
<td>3.54</td>
<td>31.17</td>
<td>3.66</td>
<td>0.70</td>
<td>534</td>
</tr>
</tbody>
</table>

* p = 0.01275, ** p < 0.00255, *** p < 0.001275, ns=not significant
completed the second course, SC308, between 2007 and 2014, there was a significant main effect due to the occasion of testing (F(1,367)=248.78, p<0.0001). This indicates that the STEB growth reported by the preservice teachers is statistically significant. The gap between the PSTE and STOE scores shown in the SC108 data is replicated within the SC308 data. Indeed, there was a significant main effect due to the STEB variable (F(1,367)=207.86, p<0.0001).

Table 6 MANOVA of STEB Data Collected during the SC308 Course

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>2995.92</td>
<td>1</td>
<td>2995.92</td>
<td>207.86</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Variable)</td>
<td>5289.58</td>
<td>366</td>
<td>14.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>2370.53</td>
<td>1</td>
<td>2370.53</td>
<td>248.78</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>3496.97</td>
<td>366</td>
<td>9.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * Variable</td>
<td>562.57</td>
<td>1</td>
<td>562.57</td>
<td>69.78</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion* Variable )</td>
<td>2958.93</td>
<td>366</td>
<td>8.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is also a significant interaction between Occasions and the variables (PSTE and STOE). This significant interaction can be perhaps explained by the fact that the PSTE scores increased more dramatically than the STOE scores. That is to say, while the STOE scores increased in a moderate fashion in this second course, the PSTE scores increased quite dramatically. This issue is picked up in the discussion on the role of the in-school experience where the students were required to teach what they had been developing in their units of work to school students.

To address the aforementioned issues related to the homogeneity of the covariance matrices, MANOVAs were computed for the separate SC308 cohorts and a similar, but not identical, Bonferroni correction was applied.
This is because analysis of seven cohorts was computed and below which a significant result is indicated. Thus the p-value is \((0.05/7)\) 0.00714 in this case. The cohorts from 2007 through to 2013, with the exception of the 2012 cohort due to missing data, showed significant STEB increases from the pre–to the post- occasion of testing.

Apart from the 2012 cohort, Table 7 below reports the means, standard deviations, effect sizes and number of students for both the PSTE and STOE scales of the STEB instrument for each of the cohorts 2007–2014. The final cohort, who completed SC308 in 2014, did not produce a significant main effect due to the Occasion of testing. That is to say, in assessing the “effect of Occasions”, MANOVA averages the PSTE and the STOE variables on both the pre– and again on the post–occasion and computes the equivalent of a correlated t-test to assess any change. This change was not significant at the protected p-value of 0.00714 from the pre– to post–occasion of testing \((F(1,15)=9.392, p=0.008)\). Such findings may be, at least somewhat, related to unexpected changes in the teaching staff for the course or to a smaller sample size or to the fact that this cohort entered the second course with already high scores on both the PSTE and STOE. Thus, perhaps a ceiling effect is at play. Regardless, six of the seven groups displayed statistically significant improvement in their STOE beliefs after undertaking the SC308 course, while all cohorts markedly improved their PSTE beliefs.
### Table 7: SC308 – PSTE and STOE Descriptive Statistics with Effect Sizes

<table>
<thead>
<tr>
<th>Year</th>
<th>PSTE Pre Occasion Mean</th>
<th>PSTE Pre Occasion Std. Dev.</th>
<th>PSTE Post Occasion Mean</th>
<th>PSTE Post Occasion Std. Dev.</th>
<th>PSTE Sig. Cohen’s d</th>
<th>STOE Pre Occasion Mean</th>
<th>STOE Pre Occasion Std. Dev.</th>
<th>STOE Post Occasion Mean</th>
<th>STOE Post Occasion Std. Dev.</th>
<th>STOE Sig. Cohen’s d</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>22.24</td>
<td>4.51</td>
<td>28.94</td>
<td>4.85</td>
<td>1.43**</td>
<td>29.50</td>
<td>3.39</td>
<td>30.45</td>
<td>3.06</td>
<td>0.29*</td>
<td>62</td>
</tr>
<tr>
<td>2008</td>
<td>26.29</td>
<td>4.81</td>
<td>29.88</td>
<td>4.42</td>
<td>0.78**</td>
<td>29.57</td>
<td>3.05</td>
<td>30.74</td>
<td>3.58</td>
<td>0.35*</td>
<td>76</td>
</tr>
<tr>
<td>2009</td>
<td>27.51</td>
<td>4.42</td>
<td>29.95</td>
<td>4.80</td>
<td>0.53**</td>
<td>30.78</td>
<td>3.29</td>
<td>31.26</td>
<td>3.28</td>
<td>0.14*</td>
<td>55</td>
</tr>
<tr>
<td>2010</td>
<td>26.33</td>
<td>3.83</td>
<td>29.10</td>
<td>5.77</td>
<td>0.57**</td>
<td>30.29</td>
<td>2.87</td>
<td>31.36</td>
<td>3.15</td>
<td>0.36*</td>
<td>42</td>
</tr>
<tr>
<td>2011</td>
<td>27.07</td>
<td>4.66</td>
<td>29.94</td>
<td>6.23</td>
<td>0.52**</td>
<td>29.46</td>
<td>3.81</td>
<td>31.96</td>
<td>3.53</td>
<td>0.68**</td>
<td>67</td>
</tr>
<tr>
<td>2012</td>
<td>Incomplete Data Set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>26.51</td>
<td>3.95</td>
<td>30.57</td>
<td>3.95</td>
<td>1.03**</td>
<td>30.90</td>
<td>3.47</td>
<td>32.71</td>
<td>3.94</td>
<td>0.49*</td>
<td>49</td>
</tr>
<tr>
<td>2014</td>
<td>27.25</td>
<td>3.82</td>
<td>30.38</td>
<td>2.71</td>
<td>0.95**</td>
<td>31.81</td>
<td>2.83</td>
<td>32.13</td>
<td>2.53</td>
<td>0.12*ns</td>
<td>16</td>
</tr>
<tr>
<td>All</td>
<td>25.99</td>
<td>4.73</td>
<td>29.76</td>
<td>3.99</td>
<td>0.86**</td>
<td>30.08</td>
<td>3.37</td>
<td>31.38</td>
<td>3.46</td>
<td>0.38*</td>
<td>36</td>
</tr>
</tbody>
</table>

* p = 0.01275, ** p < 0.00255, *** p < 0.001275, ns=not significant

In the seven years that SC308 has been offered and for which data are available, the data overall show large effect size increases (0.86) in their PSTE beliefs that are comparable to those reported in the wider literature base (0.83). The PSTE changes in this second course, SC308, are much larger than those that occurred during participation in the SC108 course.

The 2007 cohort is a curious outlier in this data set. While their final PSTE scores were comparable to other cohorts, they began the SC308 course with PSTE scores four points lower than the next lowest group (2008). From 2008 through to 2011, the effect sizes were consistently moderate. However, the groups from 2013 and 2014 showed large effect size increases in the PSTE gains. It is worth noting that the 2014 effect size increase occurred with the involvement of a less experienced teaching team. This may be a powerful comment on the educational design of the course.
For the SC308 course, the STOE subscale did not display the same level of change evident in the SC108 data set. Table 7 also shows the descriptive statistics for the STOE scores for the SC308 participants. The entire group showed a small effect size (0.38) that is also generally reflected in the small effect sizes of all but one (2011) of the separate year groups. The 2009 and 2014 cohorts displayed minimal changes with effect sizes of 0.14 and 0.12 respectively. For both of these SC308 offerings, the composition of the teaching teams was different. While this is an intriguing finding, a deeper analysis of the statistics shows that the situation may not be as negative as the effect sizes might suggest.

The issue of a “ceiling effect” may be one explanation. That is to say, the 2014 cohort entered the course with the highest mean STOE score, which suggests that there was less room for the growth necessary to produce a large effect size. Indeed, this cohort completed the SC308 course with the second highest mean STOE score. The 2014 group statistics also show a smaller standard deviation, which may imply more equitable student outcomes amongst the preservice teachers. The small sample size of 16 preservice teachers within the 2014 cohort may also be a factor in the between groups differences discussed. Broadly speaking, there was a steady increase in the mean STOE score by cohort year, which perhaps alludes to the influence of the evolving course design and the increasing expertise of the professors.

*Science Program Results*

A MANOVA was computed using the STEB scores of the 234 preservice teachers who provided data on all four occasions of testing during their respective degrees. In the tables that follow, the cohorts are named by
their year of entry and year of exit from the science program. Thus 2008-2009 means that students undertook the first science course (SC108) in 2008 and the second one (SC308) in 2009. Table 8 presents the summary output for the MANOVA analysis. It indicates that there were statistically significant main effects for the variable, the subscales, and for the occasions of testing. There is also a significant interaction for Occasions by Variable. The main effect due to the occasion of testing is highly significant (F(3,699)=95.35, p<0.0001). That is to say, participants displayed significantly greater science teaching efficacy beliefs after completing the science program. There was also a main effect due to Variable. That is to say, there is a highly significant difference in the PSTE and STOE scale scores (F(1,233)=111.20, p<0.0001).

Table 8 MANOVA of STEB Data Collected during the Science Program (SC108 & SC308)

<table>
<thead>
<tr>
<th>Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEB</td>
<td>3159.52</td>
<td>1</td>
<td>3159.52</td>
<td>111.20</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>6620.48</td>
<td>233</td>
<td>28.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>2773.91</td>
<td>3</td>
<td>924.64</td>
<td>95.35</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>6778.09</td>
<td>699</td>
<td>9.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>250.83</td>
<td>3</td>
<td>83.61</td>
<td>11.33</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>5157.18</td>
<td>699</td>
<td>7.38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Given that only 234 preservice teachers across all cohorts provided a complete set of data on all occasions, a cohort analysis was attempted as before but, unfortunately with the same result when the homogeneity of the covariance matrices was examined. That is to say, in using Cohort as the independent variable, Box’s M was again significant. Thus, individual cohort analyses were computed as before.
MANOVAs were computed for each individual cohort in an effort to examine the experiences amongst the different cohorts. As there were seven analyses undertaken, one for each cohort and one for all students across all cohorts who had supplied a complete set of data for the PSTE and STOE scales, the accepted p-value was again taken to be \( p < 0.00714 \), the full Bonferronni correction. In this analysis, only the data for the first and last occasions of testing are used in the MANOVA.

Table 9 presents the PSTE descriptive statistics for the science program by cohort group. At first glance, there appears to be considerable variance amongst the PSTE effect sizes obtained by each cohort. The 2008-2009 cohort showed a strong effect size of 1.382 while only a year later the 2009-2010 cohort produced a small effect size gain 0.245 in the PSTE. A deeper analysis of the means reveals that the variance in the effect sizes may be related to different entry scores on Occasion 1 rather than different outcomes. The difference between the highest and lowest means on the SC108 pre-occasion of testing is 7.49. Exit PSTE scores are much more uniform as the difference between the highest and lowest performing cohort is 1.32. All year groups bar the 2009-2010 cohort displayed a statistically significant main effect in the PSTE scale score due to the occasion of testing across the two years of the science program. That is to say, all cohorts bar the 2009-2010 one showed a highly significant main effect due to the occasion of testing in the PSTE scale. The 2009-2010 cohort “only” produced a significant main effect due to the occasion of testing in the STOE scale and not for the PSTE scale \( (F(1,33)=8.567, p<0.008) \) given the Bonferroni correction to the p-value. Clearly, preservice teachers who were present on all testing occasions and who appeared to have engaged fully with the science
program reported much higher personal science teaching efficacy belief scores with a mean effect size of 0.74 (Cohen’s d=0.74) in their PSTE belief scale scores.

Table 9 Science Program – PSTE and STOE Descriptive Statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>PSTE</th>
<th>STOE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Occasion SC108</td>
<td>Post Occasion SC308</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev</td>
</tr>
<tr>
<td>2007-2008</td>
<td>27.31</td>
<td>3.66</td>
</tr>
<tr>
<td>2008-2009</td>
<td>25.50</td>
<td>4.44</td>
</tr>
<tr>
<td>2009-2010</td>
<td>28.18</td>
<td>4.48</td>
</tr>
<tr>
<td>2010-2011</td>
<td>26.67</td>
<td>4.28</td>
</tr>
<tr>
<td>2011-2012</td>
<td>Incomplete Data Set</td>
<td></td>
</tr>
<tr>
<td>2012-2013</td>
<td>26.26</td>
<td>3.37</td>
</tr>
<tr>
<td>2013-2014</td>
<td>24.00</td>
<td>3.46</td>
</tr>
<tr>
<td>All</td>
<td>26.72</td>
<td>4.18</td>
</tr>
</tbody>
</table>

*=p < 0.00714, ** p < 0.00141, and *** p << 0.00141, ns=not significant

Table 9 also provides the descriptive statistics for the science program STOE scores. The preservice teachers who experienced the entire science program and who provided data for all four occasions of testing showed close to a 1-sigma growth (0.96) in their Science Teaching Outcome Expectancy beliefs. The 2008-2009 cohort showed the highest effect size change (1.51). It may be noted that the 2012-2013 and 2013-2014 cohorts completed the science program with the highest mean STOE scores. The paucity of the data over the four occasions of testing was largely driven by the Ethics in Human Research imperative of “optional participation”. Nonetheless, the cohorts
with lower completion rates (2008-2009 & 2013-2014) still produced STEB means and effect sizes that were significant.

**Discussion**

The science teaching efficacy beliefs of preservice primary teachers who participated in SC108 and SC308 grew significantly. Those who participated in SC108 showed mean effect size changes of 0.45 and 0.70 on the PSTE and STOE subscales respectively. In essence, the preservice teachers left their first science course (SC108) believing that science teaching could assist students in reaching educational goals but did not yet feel confident in their own ability to contribute to such science learning. During the second science course (SC308), participants showed growth in the reverse way. That is to say, there was large development in their STOE beliefs and low growth in their PSTE beliefs in SC108. In SC308, growth was high in PSTE beliefs (Cohen’s $d = 0.86$) and lower in the STOE beliefs (Cohen’s $d = 0.38$). The practice-base design of the SC308 may be a reason for the participants’ increased PSTE beliefs. Certainly earlier research has shown that providing preservice teachers with the opportunity to teach their group science curricula in school settings correlated with significant PSTE growth in a single week (Deehan, Danaia & McKinnon, under review - 2016). In sum, this research shows that participation in both science courses covaried with positive change in science teaching efficacy beliefs. The use of data from multiple cohorts over an eight–year period strengthens the argument for covariance between participation in the science courses and significantly increased STEBs.
The preservice teachers who experienced the full science program displayed highly significant increases in their science teaching efficacy beliefs. Between 2007 and 2014, 234 preservice teachers provided a complete data set for both science courses that comprised the science program. For this group, the PSTE and STOE mean scores increased by 0.74 and 0.96, respectively over the two-year duration of the science program. Such findings are similar to the combined STEB outcomes of the separate SC108 and SC308 courses. Given that the individuals who completed the full science program experienced different iterations of both SC108 and SC308 over different years, a strong argument can be made that the educational design of both courses covaries with the improved science teaching efficacy of participants.

A surprising trend within the data was the consistently higher STOE scores, relative to the PSTE subscale, on all occasions of testing. This is relatively unique within the wider body of literature, as PSTE scores are often significantly higher than STOE scores regardless of the occasion of testing (Deehan, 2016; Cakiroglu, Cakiroglu & Boone, 2005; Huinker & Madison, 1997; Palmer, 2006; Watters & Ginns, 1999). This trend could be related to the unusual STEB changes that occurred within the SC108 course. On average, the preservice teachers’ science teaching outcome expectancy showed larger growth than their personal science teaching efficacy over the duration of SC108. Such a finding is almost a complete outlier within the STEBI-B literature, as the PSTE subscale often shows significantly higher growth than the STOE subscale when it is reported (Deehan, 2016; Fleming, 2007; Ford, Allen, Dagher & Donham, 2011; Leonard, Barnes-Johnson, Dantley, Kimber, 2011). In fact, preservice teachers who undertook a science course based on curriculum development and practical experience showed 10
times greater growth in their PSTE scores (Mulholland, Dorman & Odgers, 2004). Nevertheless, the SC108 treatment cannot explain the higher STOE entry scores of the preservice teachers. Indeed, the findings within this paper merely hint at a future research path that is worth exploring. Deeper, qualitative research is needed both to explore the factors influencing the science teaching efficacy beliefs of preservice teachers on entry to university and to assess how these beliefs influence classroom practice. Perhaps the participants in this research had all experienced good science teaching in their high schools. Nonetheless, their STOE belief grew significantly in the first course and continued to grow in the second course.

Although the impact of the instructors was not considered overtly in the research methodology, the longitudinal data collection allows for this to be explored. There were two key instances over the eight-year period where the teaching team changed. The co-creator of the course, who has over 30 years of combined secondary and tertiary science teaching experience, was unavailable to teach SC308 in 2009 and 2014. In 2009, the co-creator was replaced by a team of academics who were less familiar with the course design. In 2014, the co-creator was replaced by an inexperienced pair of doctoral students. The STEB data from these iterations of SC308 can provide some insights into the impact of the instructors. The PSTE growth that occurred within the 2009 and 2014 offerings of SC308 were comparable to the other year groups. The PSTE of the 55 students in the 2009 group showed a moderate effect size increase of 0.59. The 2014 SC308 group showed a large effect size increase of 0.94 on the PSTE scale. One possible interpretation of this finding is that the continued development of the course design during that five year period had lessened the impact of the instructor. While the PSTE
effect sizes remained consistent, the STOE effect sizes did not reach the SC308 effect size mean in 2009 and 2014. In fact, the 2009 and 2014 groups were the only groups that did not show significant STOE growth as they recorded effect sizes of 0.14 and 0.12 respectively. This suggests that the instructor may play a considerable role in developing the science teaching outcome expectancies of preservice teachers. However, an analysis of the mean STOE scores in SC308 shows that the 2009 and 2014 cohorts exited the SC308 course with comparable STEB scores to the other cohorts. In fact, there was a consistent increase in the post-test STOE score means by cohort year. Clearly, these STEB findings cannot be attributed solely to either the instructors or the course designs. The research highlights worthwhile areas for future research. Indeed, future research should explore the relationship between instructor variables and preservice teachers’ science teaching efficacy beliefs. The instructor variable is often overlooked in the STEBI-B literature as researchers focus on either the course design or the STEBs of participants.

The use of a ‘repeated measures’ research design, over multiple cohorts, makes this research a rich and meaningful addition to the existing body of science education literature. However, this research has limitations that prevent it from extending the research into new directions. The quasi-experimental design allowed the researchers to ascertain covariance between participation in the science courses (SC108 and SC308) and the science teaching efficacy beliefs of participants, but it could not establish causal links between these variables. In order to attribute causality to the science interventions full experimental designs, with control groups, must be employed more broadly. Admittedly, ethical issues of fairness and equity in
the delivery of tertiary education make this prospect problematic. However, experimental designs are not without precedent. Scharmann and Hampton (1995) were able to implement an experimental design to show that participation in a hands-on, cooperative learning science course causes increases to personal science teaching efficacy. An experimental design with a summer program showed that PBL experiences caused greater increases in science attitudes than traditional, instructor–based approaches (Logerwell, 2009). The STEBI-B instrument could be used longitudinally to determine if any STEB changes that occur within a science intervention remain durable in the absence of treatment. Longitudinal research into the transition from pre–to in–service teaching, via the combined use of both the STEBI-B and STEBI-A instruments, could allow for a return to the fundamental goal of improving primary science teaching (McKinnon & Lambert, 2014).

There are a number of implications that arise from this research. The large effect sizes reported here on both STEB subscales for participants in the two-year science program show a need for a shift in the focus of future research. That is to say, rather than focussing on single science courses, the impacts of multiple science interventions should be considered more broadly. Certainly, consideration for the reinforcement of prior learning and transition into future tertiary courses could lead to sustained STEB growth. The modalities of the delivery of science interventions should also be considered in research designs because of the emerging prevalence of online, distance–based tertiary education. Haeusler & Lovanski (2010) were able to adapt a cooperative based learning science course for distance education. The results of the study showed that there was no significant difference in the STEB scores in either the on-campus or distance participants. If such versatility in
course delivery is made evident within the literature it could lead to more consistent and equitable tertiary science education for preservice teachers. Another implication that has emerged from this research is the need for follow-up research extending into the inservice teaching domain. It is worth determining if improved science teaching efficacy beliefs influence reported science-teaching practice, attitudes and science teaching efficacy in a tangible way. This is the subject of ongoing research by the authors.
References


Connective Statement Four

The previous publication entitled “A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers” (Deehan, McKinnon & Danaia, 2016) outlined and analysed quantitative STEBI-B data collected throughout multiple offerings of the SC108 and SC308 courses, which were first described in the second publication and initially investigated in the third publication. With 877 total preservice teacher respondents providing data on at least one occasion of testing, including complete data sets from SC108 (532), SC308 (368) and the entire science program (234), the arguments for covariance between course participation with increased science teaching efficacy beliefs and the generalisability of the findings have been strengthened. A series of MANOVAs, with modified Bonferroni corrections based on the number of tests, were conducted to determine the significance of participants’ STEB changes that occurred within SC108, SC308 and the entire science program. All but one SC108 cohort (2009) showed highly significant STEB growth, which appears to be reflective of the moderate-to-large STOE growth (Cohen’s d = 0.71) in relation to the PSTE growth (Cohen’s d = 0.49). Comparative trends were observed in the SC308 as all cohorts, with the exclusion of the 2014 cohort group, showed statistically significant changes to their STEBs. However, while the overarching growth trends for both courses were comparable, the subscale patterns were inverse as the SC308 participants showed large PSTE growth (Cohen’s d = 0.86) and small-to-moderate STOE growth (Cohen’s d = 0.38). The complementary nature of the SC108 and SC308 courses was reinforced by a four occasion science program MANOVA, wherein the output showed large growth on both the PSTE
(Cohen’s d = 0.74) and STOE subscales (0.96). The consistently higher mean scores and growth reported on the STOE subscales is unusual within the STEBI-B literature, as illustrated in the first publication (first publication).

As the evidence presented in the previous publication has shown, the cohort investigated in the third publication is not an outlier in the broader population. Thus, the claim could be made that the PSTE growth reported that occurred in the final two years of the longitudinal cohort investigation (third publication) may be representative of the larger population (fourth publication). The second, third and fourth publications have extensively described the SC108 and SC308 courses to a replicable standard and rigorously evaluated the courses through longitudinal mixed methods research and broad quantitative research. Furthermore, the broader body of literature has been critiqued and summarised (first publication) to contextualise the findings. The tertiary science education research presented across the first four publications represents a meaningful contribution to the sum of knowledge in this area of science education research. However, if the aim of improving primary science education is to be achieved, the scope of the research must extend beyond the tertiary sphere. The separate nature of preservice and inservice science education research has been shown in the comprehensive review of STEBI-B and STEBI-A literature presented in the first publication, where the instruments are seldom used to produce quantitative STEB datasets to explore the transition from tertiary to professional teaching contexts. This means that the next publication, which tracks the science teaching efficacy beliefs of the preservice teachers as they transition to inservice status, advances the extended research narrative of this doctoral dissertation whilst filling a clear gap in the literature.
The next publication entitled “From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university” (Deehan, Danaia & McKinnon, 2016) will investigate the science teaching efficacy beliefs and experiences of the prior SC108 and SC308 participants after they have graduated and established themselves as early career primary teachers. A concurrent mixed methods research design has been used to cross triangulate the STEBI-A (appendix 5, p.393) and interview (appendix 6, p.397) data. The quantitative element of the research is longitudinal as the STEBI-A data has been added to the existing STEBI-B datasets presented in the previous publication to track the STEBs of the participants after they have graduated from university and transitioned into their primary teaching careers. The tracking of individual primary teachers across four preservice testing occasions (SC108 and SC308) and one inservice occasion is unprecedented within the STEBI literature (first publication) and allows for the durability and trends of participants’ STEBs to be examined beyond the tertiary sphere. The interviews give context to the reported STEB scores by exploring science teaching experiences, tertiary science education and school science cultures. A sample of 82 graduate teachers responded to the STEBI-A and 10 gave interview data. Results showed that the graduates’ preservice STEB scores had remained durable after they had transitioned into their teaching careers. More specifically, there was a curious intersection where their PSTE scores surpassed their STOE scores for the first time. The qualitative data appears to confirm such an inference as both personal science teaching experiences and tertiary science education experiences were described in overwhelmingly positive tones whereas school science cultures were more mixed.
Publication Five

From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university.

Publication five has been submitted to the Journal of Research in Science Education (see appendix 10, p.401). Language and formatting have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Research Conceptualisation
- Data Collection
- Data Analysis
- Manuscript Drafting
- Manuscript Editing
From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university

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Abstract

The science achievement of primary students, both in Australia and abroad, has been the subject of intensive research in recent decades. Consequently, much research has been conducted to investigate primary science education. Within this literature there is a striking juxtaposition between tertiary science teaching preparation programs and the experiences and outcomes of both teachers and students alike. While many tertiary science teaching programs covary with positive outcomes for preservice teachers, reports of science at the primary school level continue to be problematic. This paper begins to explore this apparent contradiction by investigating the science teaching efficacy beliefs and experiences of a cohort of early career primary teachers who had recently transitioned from preservice to inservice status. An opportunity sample of 82 primary teachers responded to the science teaching efficacy belief instrument A (STEBI-A) and 10 graduate/early career teachers provided semi-structured interview data. The results showed that participants’ prior science teaching efficacy belief growth, which occurred during their tertiary science education, had remained durable after they had completed their teaching degrees and began their careers. Qualitative data showed that their undergraduate science education had had a positive influence on their science teaching experiences. The participants’ school science culture, however, had mixed influences on their science teaching. The findings presented within this paper have implications for the direction of research in primary science education, the design and assessment of preservice primary science curriculum subjects and the role of school contexts in the development of early career primary science teachers.

Key words: Primary science education, preservice primary teaching, transition, science teaching efficacy beliefs, school science cultures, mixed methods.
Introduction

Science education has reached a point of crisis for which there appears to be no simple resolution (Tytler 2009). This is not isolated to one country. The science achievement of both primary and secondary students across many nations has stagnated, and in some instances declined. The Trends in International Mathematics and Science Study (TIMSS), shows the science achievement scores of American, Australian, British and New Zealand 4th Grade students have declined since 1995 (Martin, Mullis and Foy 2008; Martin, Mullis, Beaton, Gonzalez, Smith & Kelly 1997; Martin, Mullis, Foy & Hooper 2016; Martin, Mullis, Foy & Stanco 2012; Martin et al. 2004). In addition, the science component of the Program for International Student Assessment (PISA) shows that the academic performance of 8th Grade students in the same nations has been largely stagnant over the same time period (Lemke et al. 2001; OECD 2004; OECD 2007; OECD 2010; OECD 2013). The lack of science development is perhaps reflective of the fact that science is often being taught in a transmissive fashion (Goodrum and Rennie 2007) or avoided altogether in the primary school (Griffith and Scharmann 2008). These findings highlight fundamental failures across systems of science education, as many students do not understand how science concepts relate to the world beyond the classroom. Aside from these lower achievement levels, students are also displaying science disengagement (DeWitt, Archer & Osborne 2014; Goodrum, Hackling & Rennie 2001), which in some instances has led to lower rates in post-compulsory science enrolments (Abraham 2013).

Given that students are passive stakeholders in science education, it would be prudent for research to focus on preservice and inservice teachers in order to effect change to science education. Primary teachers often report poor science teaching efficacy beliefs (Denessen et al. 2015), preferences for teacher-centred pedagogies (Jarvis and Pell 2005) and weak science content knowledge (Palmer 2011). Negative science attitudes may be generational as preservice and early career teachers display similar views to their more experienced peers (de La Torre Cruz and Casanova Arias 2007; Woolfolk Hoy and Spero 2005). In essence, issues exist across many levels of science
education, thus making sustained improvement inherently difficult to achieve.

Tertiary science teacher education is one of the few areas within science education that is reporting positive trends in terms of growth and change. Preparatory science education programs have been shown to enhance preservice primary teachers’ science teaching efficacy beliefs (Bautista 2011), science content knowledge (Urban-Woldron 2014) and understandings of the nature of science (Bell, Matkins and Gansneder 2010). However, the path to success at the tertiary level is not linear as there is considerable variation in terms of pedagogical approaches (Palmer 2008). Innovative approaches such as mentoring (Kenny 2012), problem-based learning (Ford et al. 2011), inquiry learning (Velthuis, Fisser and Pieters 2013), practical teaching experiences (Utley, Bryant and Moseley 2005), cooperative learning (Richardson and Liang 2008) and direct instruction on the nature of science (Bell, Matkins and Gansneder 2010) have all shown to be viable means of enhancing science outcomes for preservice primary science teachers. Science programs with multiple, interrelated pedagogical approaches may assist preservice primary teachers to develop the deep conceptualisations of the nature of science needed to address the aforementioned science knowledge deficits that are likely to be held by their future students. A reflective, alternative conception targeted approach where participants developed and taught science curricula covaried with two-sigma growth in their personal science teaching efficacy beliefs (Jabot 2002). Bautista (2011) described a similarly complex program, with the inclusion of science resources and vicarious modelling from expert science teachers, where the participants showed strong increases in both their personal science teaching and outcome efficacy beliefs.

Preservice primary teachers have been both compared with (McKinnon and Lamberts 2014), and mentored by (Kenny 2012), inservice teachers in the field of science education research. Some researchers have begun to explore the transition from preservice to inservice status within primary science education. Wingfield, Freeman and Ramsey (2000) assessed the durability of the science teaching efficacy belief growth that occurred in participants during a site-based undergraduate science program as they began their
teaching careers. The results showed that science teaching efficacy beliefs of the 31 preservice teachers remained durable for the first year of their teaching careers. Andersen and others (2004) closely analysed the science teaching efficacy beliefs of a group of 66 Danish teaching graduates during their first year of teaching. Their efficacy scores declined during this first-year due to their school context beliefs. It should be noted that this research did not include undergraduate data. Qualitative research approaches have also been used to explore graduates’ journeys from preservice to inservice status. Saka (2007) found that professional school contexts played a key role in shaping the science teaching practices and science teaching efficacy of two early career teachers. Both teachers were stressed by apparent contradictions between university and school contexts. Ginns and Watters (1999) suggest that tertiary science education may assist novice teachers to overcome school-based barriers to science teaching. Interviews and video data showed that the four early career teachers drew heavily on their tertiary experiences to construct student-centred science curricula. This paper builds upon the current body of literature by investigating the science teaching efficacy beliefs and experiences of a group of preservice teachers who have recently transitioned to inservice status.

There are undoubtedly many promising trends emerging in the tertiary science education body of literature, and yet, the aforementioned negative cycles of continue to exist amongst the science education stakeholders beyond the tertiary sphere. Clearly, more research into the transition from preservice to inservice science teaching status is needed. So many questions remain unanswered. Do the gains made by preservice teachers remain durable as they begin their early career science teaching? What factors hinder and aid science teaching attitudes and beliefs beyond the tertiary sphere for teachers? What impact, if any, do the science changes that occur during university have on the science teaching practice of early career primary teachers? The aims of this research are thus twofold. The first is to determine if the science teaching efficacy beliefs expressed by preservice teachers remains durable after they transition into the early career stages of primary teaching. The second is to explore how the early career teachers perceive their science teaching efficacy
beliefs and reported science teaching practices in relation to their tertiary and professional science experiences.

**Efficacy**

Efficacy beliefs are an individual’s judgements about both their competence to execute a task effectively and the value of the task within a broader context (Bandura 1986). Self-efficacy has shown to be one of the strongest predictors of human behaviour (Bandura 1977; 1986). In the context of education, teacher efficacy can be defined as a teacher’s confidence in both his/her own capacity and the capacity of the profession at large to enhance students’ academic achievement (Berman, McLaughlin, Bass, Pauly and Zellman 1977). Teacher efficacy is comprised of Personal Teaching Efficacy (PTE) and General Teaching Efficacy (GTE). PTE refers to a teachers’ belief that his/her teaching practice can aid students to reach predetermined educational outcomes (Coladarci, 1992; Gordon and Debus 2002). GTE is the belief that teaching practice can have a greater impact on student learning than other context factors (Tshannen-Moran and Hoy 2001). Teacher efficacy is closely related to positive teaching practice and improved student outcomes (Goddard, Hoy and Hoy 2000). Contemporary research continues to show the benefits of high teacher efficacy. A survey of 192 early career teachers showed that respondents with high teacher efficacy were less likely to exhibit symptoms of burnout and/or to express intentions to quit the profession (Høigaard, Giske and Sundsli 2012). Nie and others (2013) found that teachers with higher teaching efficacy were more likely to experiment with constructivist, student-centred pedagogical innovations. Teacher efficacy also covaries positively with student achievement levels (Cantrell et al. 2013).

Gibson and Dembo (1984) produced the Teacher Self Efficacy scales (TSES) as a valid and reliable way of measuring the intangible construct of teacher self-efficacy. A reflection of the importance of teacher efficacy is the emergence of more efficacy-based instruments in education research. Instruments such as the Mathematics Self-Efficacy Scale (Betz and Hackett 1983), the Teacher Self-Efficacy Scale (Bandura 1997), the Context Beliefs about Teaching Science Instrument (Lumpe, Haney and Czerniak 2000) and the Self-Efficacy and Knowledge Instrument for Science Teachers have all
contributed to the expansion of the teacher-efficacy literature base. The research in this paper reports on data collected from the Science Teaching Efficacy Belief Instrument A (STEBI-A) (Riggs and Enochs 1990) in relation to prior data collected from the Science Teaching Efficacy Belief Instrument B (STEBI-B) (Enochs and Riggs 1990). The STEBI-A and STEBI-B are complementary instruments that measure the science teaching efficacy beliefs of inservice and preservice teachers respectively. The science teaching efficacy beliefs of preservice teachers have been shown to have relationships with high content knowledge (Mashnad, 2008), reduced scientific alternative conceptions (Schoon and Boone 1998) and internal locus of control beliefs (Serin and Bayraktar 2014). At the inservice level, science teaching efficacy has been linked with higher rates of constructivist teaching approaches (Lardy 2011), higher student achievement (Angle and Moseley 2009) and greater satisfaction with school leadership (Clark 2009).

**Context**

The sampling pool for the current research is comprised of graduate primary teachers who completed their undergraduate teacher training at a regional Australian university between 2007-2014. These teachers had obtained a four-year Bachelor of Education (Primary) degree in their predominantly on-campus tertiary study. They undertook a minimum of 32 subjects relating to curriculum content knowledge and primary teaching pedagogies. Two mandatory science curriculum subjects were delivered as a part of the course. In their first year the preservice teachers completed ‘Science and Technology Studies I’ (SC108). In their second year they completed ‘Science and Technology Curriculum Studies II’ (SC308). Table 1 summarises the pedagogical approaches used within these science subjects.

<table>
<thead>
<tr>
<th>Pedagogical Approach</th>
<th>SC108</th>
<th>SC308</th>
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<tbody>
<tr>
<td>Constructivism</td>
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<td>Problem-Based Learning</td>
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<td>Project-Based Learning</td>
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<td>Integration with other Key Learning Areas (KLAs)</td>
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<td>In-subject practical experience</td>
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Table 1  Pedagogical Approaches used in SC108 and SC308
The two complementary science subjects incorporate multiple innovative practices identified by Lawrance and Palmer (2003) that place the students in a position of control wherein they create unique learning journeys that simultaneously develop their understandings of science teaching practice and their conceptualisations of the nature of science. Two-way assessment, structured communication (teacher-student and student-student) and ongoing professional reflection ensured that the science subjects were continuously adapted to suit the learning needs of the preservice teachers. Pedagogical Content Knowledge (PCK) (Nillson and Loughran 2011) remained a consistent focus across all iterations as science content and pedagogies were always taught in parallel. PCK can be defined loosely as the synthesis of core content knowledge in a specified area of study and the pedagogies needed to deliver this information to an intended audience (Hill, Ball and Schilling 2008). In the first subject (SC108), a problem based learning scenario was established as students were required to confront their own content knowledge deficits and alternative conceptions in the relevant field of primary Astronomy. In cooperative learning groups, the preservice teachers were required to remediate these deficits through extended micro-teaching experiences and engagement with first-hand scientific investigation.

In the first subject, the lecturer’s role changed gradually through backward faded scaffolding (Campbell and Green 2006). Specifically, the lecturer’s role began with the transmission of core information, through to the modelling of practice and ended with the facilitation of student-centred activities and investigations. This facilitative role continued into the second science subject. The students employed the core investigative skills developed in the first subject more independently in the second subject (SC308). In a simulated school setting, preservice teachers were required to work collaboratively to develop a science unit of work to address a different science content area in the curriculum than the one studied in the first subject. This allowed the
cohort to collectively share resources and address science content deficits beyond the Astronomy focus of the first subject. Throughout the second subject, the pre-service teachers developed lesson plans, used teaching technologies, conducted teaching workshops, made links to other curriculum areas and embedded assessment tasks within their work. At the conclusion of the science subjects, the pre-service teachers had developed an acceptable base of science PCK through their participation in a series of rich, authentic tertiary science learning experiences. More importantly, they had developed a diverse repertoire of scientific skills that would allow them to address any future science content deficits that may arise. The educational design of the SC108 and SC308 subjects is the subject of another descriptive paper (Mckinnon, Danaia & Deehan 2016).

**Methodology**

This research was conducted by employing a mixed-methods design with a Concurrent Triangulation strategy (Creswell, 2013). That is to say, the qualitative and quantitative data remained separate during data collection and analysis. The findings from the qualitative and quantitative data were cross-triangulated to strengthen the validity and improve the depth of the research. The separation of the methods has been used to overcome the difficulties in obtaining an adequate sample of graduate primary teachers. The sample size was increased by reducing the minimum requirements for research participation (i.e., a survey and/or an interview) (Oppenheim 2005). The quantitative data also formed part of a longitudinal assessment of pre-service teachers' science teaching efficacy beliefs as they transitioned to in-service teaching roles. The targeted population was invited to respond to a survey and/or participate in a semi-structured interview.

**Sampling**

Unlike the tertiary context, access to sufficient numbers of in-service teachers can be troublesome due to time commitments, lack of perceived benefits and geographical dispersal. The challenge in this research project was to achieve a representative sample of the targeted population of primary teachers who had graduated from a specific campus of a regional Australian university between 2007 and 2014; and who had participated in a set of science subjects
that addressed the efficacy issues. Ethical approval to conduct the research was obtained from the university’s Human Research Ethics Committee (300/2014/36). A two phase sampling procedure was employed to recruit relevant participants.

For the first phase, the university Alumni Office provided access to former graduates. An email invitation, outlining the necessary information for participation in the project, was sent to over 1,200 graduate teacher education students. While the access to such a large number of potentially relevant participants was beneficial, there were some issues with this approach. The email algorithm could not account for factors such as year of graduation; degree completed; campus attended; or, the status of the email address on file. This meant that many of the email recipients were not part of the target population. Furthermore, the risk of sending to unused email accounts was high as the Alumni Office could only access graduates’ last registered contact email addresses. Many graduates were likely to have changed email accounts as they moved into their professional teaching roles and dispersed across the country to different educational jurisdictions. This sampling phase was unsuccessful as only six participants out of the possible 1,200 provided data. This equated to a response rate of less than 0.5%.

The second sampling phase was implemented using a social media approach, where relevant individuals were targeted based on the information that they made publicly available on Facebook. Only individuals with unchanged names and corresponding location information were targeted. To maintain privacy, individuals were messaged in an open fashion with no individuals being “friended”. A total of 252 potential participants were targeted using this method. Of these, 78 graduate teachers responded in a timely fashion and chose to participate in the research. They completed the STEBI-A instrument, and 10 agreed to provide interview data. The minimum response rate for the second sampling phase was much more acceptable 31%. We have no way of knowing those who did not choose to participate, perhaps due to the infrequency of their visits to Facebook. This sampling procedure has implications for the recruitment of participants in future research.
Participants

The total number of potential participants was thus 84 (6 in the first phase and 78 in the second). Two of these had to be removed from the dataset due to incomplete submissions to yield 82 complete data submissions. Ten graduate teachers agreed to be interviewed. All of the participants were in-service primary school teachers who had graduated from the university between 2007 through 2014. The demographic data show that the employment characteristics of the sample are a fair approximation of the teaching population. Nearly three quarters (74.4%) of the survey respondents were employed in the public education sector, with the remainder working in private education (25.6%). In terms of employment status, almost a third (32.9%) of respondents held permanent positions within their schools. Many respondents were teaching on year-long temporary contracts (45.9%), with the remainder (20%) working on a casual basis in schools near to their homes.

Instruments

Data were collected using quantitative surveys (STEBI-A + demographics) and qualitative interviews. The use of both qualitative and quantitative measures allowed for cross triangulation to produce more accurate and valid findings (Creswell 2013). The data collection instruments and methods are briefly explained below.

The Science Teaching Efficacy Belief Instruments (-A and -B)

In their undergraduate degree, graduates experienced two science subjects where they had been invited to complete the STEBI-B (Enochs and Riggs 1990) at both the commencement and conclusion of each subject. They thus responded to the instrument four times over a period of two years. Respondents’ prior preservice teacher STEBI-B data were intended to be matched with their responses on the STEBI-A instrument. This was done to make comparisons between participants’ preservice and in-service science teaching efficacy beliefs. Of the 82 respondents, a total of 44 of the survey respondents had complete sets of undergraduate STEBI-B data that allowed for longitudinal analyses to be computed over the five occasions.
The STEBI-A (Riggs and Enochs 1990) measures the science teaching efficacy beliefs of inservice teachers through their responses to statements on a 5-point Likert scale ranging from ‘Strongly Agree’ to ‘Strongly Disagree’ (Burns 2000). The instrument produces the same two subscales as the STEBI-B: Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). The PSTE subscale measures respondents’ beliefs about their capacity to guide students towards science learning outcomes effectively. An example of an item on the PSTE subscale is “I am continually finding better ways to teach science”. The STOE subscale measures respondents’ beliefs about the capacity of science teaching to overcome perceived hindrances to improve students’ science outcomes. An example of an item of the STOE scale is “When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach”. The seminal authors reported Cronbach’s alpha reliability scores of 0.92 on the PSTE scale and 0.74 on the STOE scale (Riggs and Enochs 1990).

The 82 completed STEBI-A surveys were used to assess the same subscales formed from the items employed in the STEBI-B instrument; which produced Cronbach’s alpha reliability coefficients of 0.89 and 0.79 on the PSTE and STOE scales respectively on the final occasion of undergraduate testing at the completion of the second science course (Deehan, McKinnon and Danaia 2016). Analyses showed that the same scales formed from the same items also produced reliable subscales in the STEBI-A instrument: PSTE (Cronbach’s alpha = 0.81), and STOE (Cronbach’s alpha = 0.81). The similar reliability coefficients for both the subscales on both the STEBI-A and STEBI-B instruments, we argue, makes the scales equivalent. Thus, both the STEBI-A and STEBI-B instruments reliably measure the same subscales with only minor phrasing changes made by Enochs and Riggs (1990) to suit the different the educational contexts of the participant groups.

*Semi-Structured Interviews*

The semi-structured interview approach provided the researcher with a consistent base of qualitative data that was relevant to the research questions whilst still allowing for potentially unforeseen, inductive themes to be
explored naturally during the exchanges (Burns 2000; Cohen, Manion and Morrison 2001; O’Toole and Beckett 2013). The 10 interviewees responded to demographic questions alongside questions probing three key areas of inquiry: science teaching practice; tertiary science education experiences and school science culture. Four of the interviews were conducted in a face-to-face format. An additional five respondents elected to have their interviews conducted via telephone, thus still allowing for immediate follow-up questioning. This approach was adopted because of their remoteness from the interviewer. One participant opted for an email exchange which prevented immediate follow-up questioning. All verbal interviews were recorded and transcribed by the first author.

Data Analyses

The inservice STEBI-A data of the respondents were compared with prior preservice STEBI-B data in two ways. First, the mean scores on the PSTE and STOE subscales across the four preservice occasions (viz., the pre- and post-occasions of testing in each of the SC108 and SC308 science subjects) and the single inservice occasion were plotted and analysed in order to provide a holistic picture of change in the combined datasets. Second, Multivariate Analysis of Variance Analyses (MANOVAs) with repeated measures on the occasion of testing were used to evaluate the magnitude of any changes in the science teaching efficacy beliefs of the inservice teachers who had provided STEBI-A data (Coleman and Pilford 2008). This procedure was chosen because there are two dependent variables from a group of participants matched across multiple testing occasions (O’Brien and Kaiser 1985). In this research, the MANOVAs allowed an investigation of the durability of the respondents’ PSTE and STOE scores as the transitioned from preservice to inservice status. The first MANOVA assessed the significance of any STEB change from the final preservice occasion of testing to the inservice occasion of testing. The final MANOVA assessed the significance of STEB changes of the 44 graduate teachers who provided full data on all four preservice testing occasions and on the inservice testing occasion. Cohen’s d effect sizes were calculated to determine the relative strength of the STEB changes. Tests for homogeneity of variance and the equality of the
covariance matrices were also computed to ensure that the mathematical assumptions of MANOVAs were met.

Initially, the interview data were manually analysed in a thematic fashion. This provided a holistic, contextually bound understanding of the data. The next step involved coding the data for consistency and clarity without altering the meaning of the text. To avoid bias, these analyses were supplemented with a syntactical analysis using the Leximancer software. Leximancer software accounts for researcher bias by analysing word semantics and text proximity (Smith and Humphreys 2006). The Leximancer output was examined to detect any trends that conflicted with the manual analyses. No such conflicts were found. That is to say, the themes and concepts identified by the Leximancer software were consistent with those identified through the manual analysis.

The interview transcripts were then coded using QSR NVIVO 10 software. Core themes were organised based on the structure of the survey questions. The three core themes reported in this paper are Tertiary Science Experiences, School Science Cultures and Science Teaching Practice. Core sub-themes were identified inductively through re-reading of the transcripts. The strength of each sub-theme was assessed through both the frequency of contributing participants and the frequency of mentions within the text. The relationships between the three core themes were further analysed manually. Unbroken participant responses (i.e., statements unbroken by interviewer input) that addressed at least two of the key themes were analysed in terms of both the effect (positive/negative) and directionality of the intra-theme relationships.

**STEBI Findings**

A Multivariate Analysis of Variance was conducted on the both the final tertiary STEB scores and in-service STEB scores of 75 graduate primary teachers. The output of this MANOVA is summarised in Table 2. It appears as though the difference between the PSTE and STOE subscale scores is indeed marginal as there was no significant effect due to STEB (F(1,74)=0.264, p=0.609). Such parity between the PSTE and STOE subscales is relatively unique within both the STEBI-A and STEBI-B literature (Deehan, 2016). The PSTE subscale showed moderate growth
(Cohen’s $d = 0.39$) and the STOE subscale showed small decline (Cohen’s $d = -0.27$). However, there was no significant effect due to the occasion variable ($F(1,74)=0.348, p=0.557$). The null hypothesis that there is no difference between the STEB scores on the preservice to inservice testing occasions must be accepted. This serves as evidence that the STEB gains made during two preservice science education subjects remain durable after the respondents’ transition to professional teaching. The preservice science education subjects are investigated further in two other publications (Deehan, Danaia & McKinnon 2016; Deehan, McKinnon and Danaia 2016).

Table 2 MANOVA of the STEBI Data Collected on the Final Tertiary Occasion and the INSERVICE OCCASION

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEB</td>
<td>4.320</td>
<td>1</td>
<td>4.320</td>
<td>.264</td>
<td>0.609</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>1209.680</td>
<td>74</td>
<td>16.347</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>3.413</td>
<td>1</td>
<td>3.413</td>
<td>.348</td>
<td>.557</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>725.587</td>
<td>74</td>
<td>9.805</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>125.453</td>
<td>1</td>
<td>125.453</td>
<td>24.204</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>383.547</td>
<td>74</td>
<td>5.183</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 shows the mean PSTE and STOE scores produced across the two tertiary science subjects for those undergraduate students who had provided data on all four testing occasions (broken lines) and the respondents who had also provided data on the inservice testing occasion (unbroken lines). The inservice teachers appear to be representative of the respondents who had provided data during their undergraduate studies. This argument is based on the observation that the broken and unbroken lines for the first four occasions of testing are broadly similar.
To test the observations made of Figure 1 we computed a MANOVA with repeated measures on the occasion of testing for all students who provided a complete dataset during their undergraduate studies but with the group membership employed as the IV to test the representativeness of the graduate teachers who provided data post-university. There was no significant main effect due the independent variable of group membership ($F(1,232)=0.611$, $p=0.435$). None of the relevant first and second order interactions were significant: Group by Occasions ($F(1,232)=0.609$, $p=0.436$) and STEB variables by Occasions by Group ($F(1,232)=0.826$, $p=0.364$). That is to say, the inservice teachers who provided additional data compared with the undergraduate students appear to be a representative sample of all of the people who had experienced the two science subjects while undertaking their university studies. The only significant main effects are due to the occasion of testing ($F(1,232)=107.32$, $p < 0.0000001$) and to the efficacy belief variables PSTE and STOE ($F(1,232)=69.72$, $p < 0.0000001$). Thus, both groups improved their efficacy beliefs in similar ways with their STOE belief being significantly greater than the PSTE belief while they were at university.

Of the 82 teachers who provided data on the inservice occasion, 44 provided complete sets of STEBI data on all five occasions of testing. The inservice occasion of testing marks the only period where the inservice teachers’ PSTE belief exceeds their own STOE belief in science teaching. A MANOVA was computed on the STEB data across these five occasions of testing to explore
the combined effects of preservice science teacher education and early career teaching experiences. The summary output is presented in Table 3.

**Table 3** MANOVA of the STEBI Data Collected on all Four Tertiary Occasions and the Inservice Occasion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEB</td>
<td>483.00</td>
<td>1</td>
<td>483.00</td>
<td>18.65</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>1095.50</td>
<td>43</td>
<td>25.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>826.42</td>
<td>4</td>
<td>206.60</td>
<td>18.55</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>1915.59</td>
<td>172</td>
<td>11.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>256.74</td>
<td>4</td>
<td>64.18</td>
<td>9.43</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>1171.26</td>
<td>172</td>
<td>6.81</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows that there is a highly significant effect due to the occasion of testing (F(4,172)=18.55, p < 0.0001). There is a significant effect due to the STEB variable (F(1,43)=18.959, p < 0.0001). There is also a significant interaction of the occasion of testing by the STEB variables (F(4,172)=9.43, p < 0.0001). The latter two results can best be explained by the fact that the STOE beliefs were consistently higher than the PSTE beliefs until the inservice testing occasion, and the fact that the PSTE beliefs showed greater growth that extends beyond the science subjects. Effect sizes were computed for the two scales from the first occasion of testing to the final one. The PSTE displayed a very large effect size increase (Cohen’s d=1.33), whilst the STOE showed moderate positive change (Cohen’s d=0.60). While threats to validity, such as the inability to attribute causality and the likelihood of maturation have to be considered, the findings suggest that the graduate primary teachers have developed strong, positive science teaching efficacy beliefs over the course of their tertiary study that have remained durable and resilient during their transition to early career teaching. Such findings have implications for how the graduates perceive themselves in relation to other primary science teachers they encounter in their schools.

**Qualitative Findings**

The qualitative findings derived from the interviews are presented under three core themes. First, the Tertiary Science Experiences of the respondents are analysed and discussed. Second, the School Science Culture theme is unpacked with emergent sub-themes. Third, the reported Science Teaching
Practices of the respondents are presented. Finally, a short conclusion describes the relationships amongst each of the three key themes.

**Tertiary Science Experiences**

All 10 of the interviewees discussed their reactions to the tertiary science education that they had received. The interviewees all expressed positive reactions to their tertiary science education experiences with varying degrees of emotional conviction. Jeremy noted how crucial the subjects were to his development as a science teacher in an almost offhand way, ‘They were probably two of the more influential subjects in the course’. Francis spoke in almost reverential tones about her science experiences as an undergraduate student, ‘I’m thinking how lucky I was. I really am, looking back it was just champagne education’.

Table 4 summarises the emergent sub-themes and indicates the number of participants (Sources) who mentioned the theme together with the total frequency of discussion by all involved (Mentions). The complexity of both subject designs is reflected in the considerable variation and specificity in the emergent sub-themes. The interviewees all reflected on different pedagogical elements and their educational experiences, which might be an indicator of the reflexive and personalised nature of these tertiary science subjects. Notable sub-themes included: Cooperative learning (11); Student Centred Learning (10); Relationship with Teaching Staff (10); Alternative Conceptions (9); Value Beyond Science Teaching (7); and Pedagogical Content Knowledge (5).

**Table 4 Summary of the Tertiary Science Experiences Sub-themes**

<table>
<thead>
<tr>
<th>Sub-Theme</th>
<th>Number of teachers (Sources)</th>
<th>Frequency of being mentioned (Mentions)</th>
<th>Innovative practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative Learning</td>
<td>6</td>
<td>11</td>
<td>*</td>
</tr>
<tr>
<td>Student Centred Learning</td>
<td>5</td>
<td>10</td>
<td>*</td>
</tr>
<tr>
<td>Relationship with teaching staff</td>
<td>4</td>
<td>10</td>
<td>*</td>
</tr>
<tr>
<td>Alternative Conceptions</td>
<td>5</td>
<td>9</td>
<td>*</td>
</tr>
<tr>
<td>Value Beyond Science Teaching</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Pedagogical Content Knowledge</td>
<td>5</td>
<td>5</td>
<td>*</td>
</tr>
</tbody>
</table>

*Denotes pedagogical approaches used within the science subjects cross referenced with Table 1
Contrary to prior research that showed preservice teachers’ negative emotional responses to cooperative learning (Author 2013), all mentions of cooperative learning showed favourable attitudes to its pedagogical value. In her reflection as a graduate teacher, Georgina was able to distance herself from the personal difficulties that she experienced in her undergraduate science training:

I think the heavy focus on group work really made you. I guess now that I’m in a school and reflect back on that and say yes it is tricky working with some people. But it can really pay off when you’re with the right people and you get the right combination.

Five graduate primary teachers discussed Student Centred Learning when reflecting on their tertiary science education experiences. Danielle expressed appreciation for the control she was afforded when she began the SC308 course:

I had so much fun learning the different things in it, like the way [Lecturer] showed it I found really interesting. It was also a bit, I suppose, [Lecturer] let us run it a bit more. In our second science subject where we did the lessons, I think that was it.

Inquiry learning, student control and practical science teaching experiences were all discussed as favourable aspects of the interviewees’ science education experiences. Ian described the process of inquiry he now adopts when planning science lessons for his students:

I knew that these are the things that I was to get out of the kids, now how do I find an appropriate lesson for it and how do I find the information to do it. So I think that the process of how to get that information worked.

Four of the graduates mentioned the positive relationship they had with the lecturer during their tertiary science experience and highlighted the impact this relationship had on their science teaching practice. This is epitomised in the following quote from Charlotte:

But I do try to do it [teaching science] justice, and because I know [lecturer] on a personal level I want to do him proud. It’s hard…Like I said I enjoy science, but I think it is due to my relationship and [lecturer] that I try and make it the best that I can. I mean I enjoy it, and not saying that I hate…or want to do worksheets, I enjoy what I am doing and I think the kids are enjoying it a lot more too. Everyone needs that relationship with [lecturer] so they will do it better!!

Five graduate teachers mentioned Alternative Conceptions. They described their reactions to the results they obtained in the Astronomy diagnostic test presented in the SC108 course upon their entry into tertiary study. Terms such as ‘wakeup call’ and ‘embarrassed’ indicate that the participants initially had
negative reactions when confronted with their low levels of Astronomy content knowledge. It appears as though the graduates’ vivid memories of being confronted with their alternative scientific conceptions served as motivation as they progressed through the science program. After being ‘devastated’ by her low score on the pre-test SC108 Astronomy diagnostic, Hayley stated that she ‘ended up getting 19 out of 20’ at the end of the course. Danielle discussed how her own alternative conceptions engaged her in science learning:

The misconceptions I had shocked me, and so I loved that we started with that so we could find out how much we didn’t know and then I was keen to learn about it. I found that that was really good and now I actually want to go and teach that.

For many of the interviewees the value of their tertiary science education was far reaching. In fact, six of the interviewees noted the influence that the two science subjects have had on their broader roles and responsibilities as generalist primary teachers. Hayley discussed the professional relevance of her second science subject (SC308):

I really enjoyed that subject; I think that creating that Unit of Work was really important. I think it should be done all the time because it’s just such a stepping stone for when you come into the workplace where you can apply that knowledge to everyday stuff.

Five of the graduates touched on the construct Pedagogical Content Knowledge during their interviews. They enjoyed the balance between pedagogy and content that was central to their tertiary science experiences. Hayley expressed gratitude that aspects of PCK were modelled within the course:

I remember [the lecturer] doing quite a few demonstrations and I’m a real visual learner so I really benefited from that type of teaching. Yeah it was quite hands on. I really enjoyed that.

**School Science Cultures**

School Science Culture was the second prominent theme to emerge from the interview data, as the interviewees’ professional contexts were central to their science teaching practices. The interviewees’ perspectives and science teaching practices were open to influences from a varied array of external sources. All of the science culture sub-themes mentioned were beyond the immediate control of these early career primary teachers. Table 5 summarises
the number of participants (Sources) who mentioned the sub-theme together with the total frequency of discussion by all involved (Mentions).

Table 5 Summary of the School Science Culture Sub-themes

<table>
<thead>
<tr>
<th>Sub-Theme</th>
<th>Number of teachers (Sources)</th>
<th>Frequency of being mentioned (Mentions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influence of Other Teachers and School Executive</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>Priority of Science</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>Science Marginalisation in School and Outsourcing to RFF Teacher</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>Resources Available for Science</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>Access In-School Support and/or Professional Development</td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>

For most of the interviewees, the influence of other teachers emerged as a leading sub-theme within their discussion of school science cultures. Bruce noted that the open communication between his colleagues and himself facilitated his continued reflective practice, which he believed had enhanced his science teaching. Eliza appreciated that a team of teachers within her school provided professional development to assist others to understand changes that had been made to the science curriculum. Georgina’s school provided similar collegial support for the transition to a new science curriculum. She described, with pride, an inquiry based built environments unit of work that a colleague and herself had planned together.

Unsurprisingly, a valuable supporting mechanism for the early career teachers was the opportunity for science teaching collaboration with their more experienced colleagues. Eliza appreciated that she was able to both offer support to, and receive it from, her more experienced colleagues, ‘I enjoyed sharing my strengths in technology and she [teacher] could share her knowledge of curriculum and resources’. When asked about the general science teaching support, Georgina responded by saying, ‘It’s really just a collaborative environment’.

Ideally, the school science culture can be a key positive factor in sustaining their efficacy beliefs and helping them to have positive experiences in their own early career science teaching practices. School Executives were valued by the interviewees for their openness to new ideas, immediate programming support and science leadership. Hayley’s school executives had implemented
a school wide science and technology teaching tool. She spoke passionately about the technical support she offered to her more experienced peers in response to the science teaching guidance of which she had long been a recipient. Hayley described the school-wide science programming process at her school:

My stage leader is phenomenal. She’s always ready to sit down when we’re developing these Science and Technology Tools (SATTs). We had a pretty full-on staff meeting learning about the SATT tool. So that’s probably number one was getting help through understanding the SATT tool and being able to apply it to the PrimaryConnections information that we’d designed ourselves. I think we did it on our first day back at the start of the year. We worked on that with the principal as well. Yeah, pretty much everyone’s got a different input on all of it. All the teachers who have taught the content before are always good for advice. The new ones working here, we’re a bit more open minded to the technology that goes into it. So I think it’s really good. The support at my school is amazing.

Danielle was pleased that her stage team had co-constructed a suite of science resources. Still, she admitted that aside from the dispersal of physical resources, the collegial support was limited. Others provided further insight into the potential for other teachers to have a detrimental influence on school science cultures. The egalitarian norms, which are common in the teaching profession (York-Barr and Duke 2004), had a profoundly negative impact on Charlotte. Whilst sharing pictures of the bottled rainforests that she had created with her class, another colleague interrupted with ‘Don’t be an overachiever Charlotte!’ Francis was faced with a similar challenge when she was told to ‘Just let it go’ when she remarked that a colleague was teaching alternative scientific conceptions to a group of students.

The crowded curriculum was mentioned by eight interviewees as a reason for Low Science Priority within their schools. Ashleigh noted that her literacy and numeracy teaching had to remain the highest priority as a beginning teacher, ‘When you’re a beginning teacher, your areas of focus are possibly more than literacy and numeracy’. Conversely, Ian felt restricted by his school’s restrictive focus on literacy and numeracy:

My sense was that [science] wasn’t valued. You had a school where you had the first block of the school was English and just English. [And] The next block, the half of it was just maths. If you did anything else during those times you would get hauled over the coals for it.

There are additional aspects of school science cultures that could also have negative influences on the interviewees’ perceived capacity to teacher science
effectively. Low Science Priority and Science Marginalisation were both prominent sub-themes at this level of the qualitative analysis. Four of the interviewees openly stated that science was not a priority within their schools. Eight of the interviewees shared their observations of science marginalisation in their school contexts. Even though Danielle taught casually in a single school for a year, she was unable to recall any instances where science had been mentioned or taught:

I actually don’t know how they taught science. I never actually saw a science lesson. I taught a Year 5 class for a week and we didn’t do science once.

For Charlotte, science was often marginalised in her school as the subject was combined with Human Society and its Environment (HSIE) in weekly blocks for one hour. Six of the graduate teachers had their science teaching practice compromised by school-wide imperatives to outsource science teaching to RFF teachers. Two of the graduate teachers became science relief teachers during their first years as primary teachers. Jeremy became a full-time science RFF teacher after the completion of his final undergraduate teaching internship. Such intensive science teaching experiences were likely to be beneficial to the science teaching practice of these early career teachers. However, Georgina provided some interesting insights as she described the difficulties she experienced when she taught science in this relief role, ‘I think if I was in this class five days a week I would be fine, because then we would have that environment where we could take risks. But I’m in here two days per week and I’m struggling to get through this content’. Perhaps relief science teaching limits teachers’ capacity to implement long-term, student-centred investigations.

When asked about access to resources, many of the interviewees spoke of intangible elements such as collegial support. In fact, while only four teachers mentioned practical teaching resources, they stated that the availability of such resources in their schools was highly limited. Jeremy stated that he had had to change his science teaching practice due to the lack of resources, ‘I didn’t have the materials to do too many hands-on activities’. Despite the somewhat negative impact of the lack of resources sub-theme, PrimaryConnections materials (Hackling 2006) were discussed favourably by all 10 interviewees. It appears that the PrimaryConnections resources serve
as a useful foundation to make syllabus and content connections. Georgina displayed her developing science PCK as she reflected on her use of this resource, ‘I read the PrimaryConnections textbook and thought Hm.. I can teach this better without the worksheets. So I brought the lamp in and did all of the hands-on things.’

Although they recognised the challenges of the crowded curriculum, Bruce and Hayley both valued the deep learning opportunities afforded by broader cross-curriculum integration. Bruce noted, ‘We have an assembly so that takes away time. You know, all those little things that pop up. A lot of things happen together. Science, maths and English are so interrelated’. He also reflected deeply on the planning processes needed to ensure that the links with science created opportunities for higher order thinking (Krathwohl 2002). Hayley saw cross-curriculum integration as a way of introducing science to her program after the subject was outsourced to a specialist RFF teacher by the school executive:

I tried to incorporate little experiments into my class anyway, based on other Key Learning Areas (KLAs). So we did the ice melting, grease and fats experiment, colour changing milk and we did some potions for maths. I was still able to do little things that were quite scientific, based on the other KLAs.

Not to be deterred from their intended science teaching practice, Ian and Charlotte both elected to collect resources from outside the school. Charlotte attempted to strengthen her influence on the school science culture by volunteering to restructure her school’s science scope and sequence to reflect the new syllabus outcomes and the available resources. There is some evidence to suggest that the interviewees were able to overcome obstacles to their science teaching practice from within their school contexts. The graduate teachers seem to be displaying a resilience that may have positive effects on their school science cultures.

Access to internal support and external professional development were inconsistent for the interviewees. Six of the interviewees reported low levels of internal support for science teaching offered within their school contexts. Jeremy noted his school ‘didn’t have a science room or a science budget’. Charlotte summed up her reasonably common experience, ‘we’re sort of left to our own devices really’. Collaborative programming, team teaching and open dialogue were deemed valuable, if inconsistent, supports but were based on
efforts from individuals rather than whole schools. Three of the interviewees were given opportunities to attend external science professional development seminars, with Hayley attending a multi-school professional learning day, Jeremy receiving training in the new science curriculum and Charlotte undertaking professional development in the PrimaryConnections science program.

**Science Teaching Practice**

The reported science teaching practice of the graduate teachers was an explicit area of focus in the qualitative data analysis. All but one of the interviewees had obtained noteworthy science teaching experiences as early career teachers. Table 6 outlines the key Science Teaching Practice sub-themes that emerged from the interview data. Despite the mixed reports of school science cultures, the majority of the sub-themes suggested positive trends of the science teaching practices of the early career teachers. Deep, student-centred pedagogical sub-themes such as Inquiry Investigation, Hands-On Learning and Student-Centred/Facilitation suggest that the science teaching practice of the graduate teachers may have been influenced by their tertiary science experiences. The sub-theme “Above and Beyond/Confidence” shows that a number of interviewees may have extended their influence beyond their immediate classrooms to the broader school contexts.

<table>
<thead>
<tr>
<th>Sub-Theme</th>
<th>Number of teachers (Sources)</th>
<th>Frequency of being mentioned (Mentions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student-centred Approaches</td>
<td>9</td>
<td>53</td>
</tr>
<tr>
<td>Above and Beyond/Confidence</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>Reflective Practice and PCK</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>Student Response</td>
<td>9</td>
<td>19</td>
</tr>
</tbody>
</table>

Inquiry, hands-on and student-centred pedagogies were reported by all interviewees who were in a position to teach science. Ashleigh indicated that sensory, hands-on experiences were central to the science lessons that she delivered to special needs students. Charlotte’s students both made and collected data from bottled rainforests. Some of the interviewees displayed advanced pedagogical reasoning. Jeremy described the incorporation of multiple science pedagogies into his science teaching practice:
We did research, we made shoeboxes with light, so how light travels. We were reflecting with mirrors. So the extension group did the activity and then they had to come up with their own, they had a variation on that activity. So, what else? What other things can we use? They went off with the materials, instead of just making a periscope, you can use a mirror to change the direction of light. They had to see other ways they could manipulate and make changes to it. It’s more hands on and more freedom for them.

Reports of strong science teaching confidence are likely to be related to the interviewees’ science leadership roles as they extend above and beyond the science teaching requirements of general primary teachers. The interviewees were generally confident of their ability to teach science, ranging from Ian’s high science teaching confidence, ‘I absolutely love it’ to Georgina’s more moderated confidence as she still remained ‘a bit unsure’ while she reflected on her discomfort with relinquishing control. The interviewees’ claims about their high science teaching confidence appear to be substantiated by the science-based roles that they have taken within their school contexts. There were seven graduate teachers who undertook science roles and responsibilities that extended beyond general teaching requirements. Three interviewees (Danielle, Georgina and Hayley) played lead roles in the development and resourcing of school science curricula. Hayley presented her school’s science tool at an inter-school professional development workshop. Similarly, despite their relatively limited experience, Jeremy and Charlotte were their schools’ sole representatives at science professional development workshops. After running a science interest club for the entire school, Ian became a science advisor for his more experienced colleagues. In just her second year as a regular classroom teacher, Charlotte had been assigned the role of Science and Technology Coordinator within her school. This evidence suggests that these early career teachers were becoming agents of positive growth within their school science cultures.

Student response to science learning was important for all interviewees who were in a position where science teaching was required practice. Interviewees reported overwhelmingly positive student responses to their science teaching practice, with words such as ‘engaging’, ‘hands on’ and ‘exciting’ emerging as descriptors. Charlotte proudly described her class’s response to a life cycles science unit:

They love it. With the seeds and the rainforests they would run, because I would let them water their own plants in the morning, so they would all be on their best
behaviour because they would want to be chosen to water the plants. They would always be asking, can we take our seeds home today, when can we take our rainforests home and that sort of thing. So they had obviously been talking about that sort of thing at home. We took the seeds home about half way in, so they have had them at home for about 5 weeks, and some have said that they have planted them in their veggie garden, and they are ready to have lima beans, it’s good that they have continued it at home, they didn’t let it wither and die. They still cared for it, which means that it obviously meant something to them.

Jeremy discussed how his student-centred approach to science teaching was received by his students:

They enjoyed it because they had the freedom to think for themselves instead of just teacher directed extension. They responded really well to it because it was their ideas, it was their discussions and their work. It wasn’t ‘this is what you’ve got to do, hand it in when you’re done’.

The incorporation of multiple pedagogies stemming from professional reflection may show that the graduate teachers are developing the reflexive PCK that is often displayed by master science teachers. Mitchell, Pannizon, Keast and Loughran (2015) describe non-linear, rapid pedagogical reasoning as Pedagogical Pinballing. While the early career teachers in this study may not yet have the highly developed, intrinsic capacity for pedagogical pinballing of their more experienced counterparts, there is evidence to suggest that they are reacting to ‘in the moment’ variables as they construct non-linear science learning experiences. Ian was able to respond immediately to resource barriers by moving seamlessly through his repertoire of science teaching pedagogies:

I was quite disappointed that they didn’t have much in terms of science. The one thing that they did have was a circuits kit. So I was the first to use that on my stage and I basically ran that with a guided investigation. I gave them a bag with the things that they needed and said ‘turn the lightbulb on’. It was quite interesting watching them do that. Yeah they were quite good. Then I even went with the approach where I picked two kids in my class that really, really got on board with the science and I gave them the kits and they took themselves off to the year 3 classrooms and they actually taught science to the year threes. So there were three year three classes, so I sent six of my kids down and they all taught their own science, so that was pretty good too.

Their tertiary science experiences appear to play a leading role in their conceptualisation of high quality science teaching. Despite believing that she was teaching science to a higher standard than some of her peers, Charlotte was still working towards the standards set during her undergraduate science education:

...so I know that I am teaching science, even though I know that...after [Lecturer]...I’m not doing the best job I could be, but I still feel that I am doing a better job than some others.
Connections between the Themes

A manual analysis of the interview transcripts was conducted to determine how the graduate teachers linked the three key themes of Tertiary Science Education, School Science Culture and Science Teaching Practice. The influence of the Tertiary Science Education and School Science Culture themes on the interviewees reported Science Teaching practices was of particular interest. Figure 2 shows the relationships between the themes. Each time two themes were mentioned in the same block of text, the samples were coded for the direction of influence and the type of influence (positive or negative). The dotted arrows denote negative influences and the solid arrows denote positive influences. The School Science Culture had an almost even split of both positive (42) and negative (46) influences on the Science Teaching Practices of the graduate teachers. Conversely, the Tertiary School Experiences of the participants had an overwhelmingly positive (45) relationship with their Science Teaching Practices. More broadly, the mentions of enabling factors (87) outweighed the mentions of hindrances to science teaching (47). Such trends hint at a powerful narrative wherein the early career teachers’ tertiary science experiences are bolstering their capacity to cope with negative influences from within their school science cultures. More research is needed to explore these relationships but the reports of high science teaching confidence, student-centred teaching and science leadership lend credence to such an interpretation.
Discussion

The STEBI-A data showed that the science teaching efficacy beliefs of the participating graduate teachers had remained durable as they transitioned from preservice status to early career primary teachers. There was no statistically significant difference on the participants’ science teaching efficacy beliefs from the preservice to the inservice occasion of testing. An analysis of the PSTE and STOE means on the inservice and preservice occasions reveals an intriguing interaction. A small decline in the STOE subscale (Cohen’s $d = -0.2728$) when considered in relation to a moderate increase in the participants’ PSTE scores (Cohen’s $d = 0.3899$), represents the first time that their personal science teaching efficacy beliefs are higher than their outcome expectancies for science teaching in a more general sense. This finding hints at a promising, desirable mindset for these early career primary science teachers. The STOE findings suggest that the early career teachers may have shed their idealistic conceptions of the capacity of science teaching to improve student outcomes whilst avoiding more cynical outlooks. Cross triangulation reveals that the interviewees were able to recognise external hindrances to effective science teaching whilst still believing that teaching was the most important factor in students’ science learning. Their increased
PSTE beliefs are a testament to where the respondents place themselves within their school hierarchies. The early career teachers appear to believe that they are meeting, or even exceeding, their own internal expectations for science teaching. The graduate teachers’ tertiary science experiences and early career teaching experiences appeared to have had positive impacts on their science teaching efficacy beliefs.

The interview data provided some intriguing insights into how the early career teachers’ reported science teaching practices may have been influenced by their tertiary science education experiences and their school science cultures. All of the interviewees claimed that their tertiary science education experiences (SC108 and SC308) had influenced their science teaching practice in a positive manner. Their unique responses reflected the diverse array of pedagogical innovations that underpinned the complementary SC108 and SC308 subjects. Alternative conception targeting, cooperative learning, differentiation, assessment, inquiry learning and PCK development were all described positively by multiple interviewees. Deep reflection was evident as six of the interviewees believed that their tertiary science experiences held considerable value beyond science. One interviewee described the science subjects as “two of the more influential subjects” that he experienced during his four years of tertiary study. The School Science Cultures of the interviewees had mixed impacts on their reported science teaching practices. None of the interviewees described completely negative school science environments; in fact many were pleased with the peer support offered, the science leadership of the school executives and the programming resources that were available to them. There were several hindering themes that emerged frequently within the qualitative data, including the crowded curriculum, science marginalisation, other teachers, limited resources and the low priority of science. While these hindrances have been noted in existing research (Goodrum, Hackling and Rennie 2001), how the interviewees responded to these factors is the point of difference. Rather than using external hindrances as excuses for avoiding or marginalising science (Angus et al. 2004), the early career teachers in this research displayed resilience as they integrated science with other KLAs, found alternate resources for their science lessons and varied their pedagogical approaches in order to react to
perceived constraints. There is some evidence to suggest that the graduate teachers’ positive experiences at the tertiary level assisted them to overcome negative influences from their school science cultures.

The researchers’ initial focus on STEB durability reflected the negative state of science education and the relatively low status of early career teachers within school systems. It was hoped that these early career graduate teachers would show durable science teaching efficacy beliefs as they were confronted with firsthand experiences of the issues that currently exist in primary science education. Some inductive trends emerged from the data that indicated this might have been a pessimistic conceptualisation of the research, as teachers appeared to be thriving as active agents of change rather than just surviving in existing school science cultures. Resilience emerged as a central theme as interviewees used integration to avoid the crowded curriculum, actively sought out teaching resources and took risks with student-centred pedagogical approaches. Other graduate teachers began to eschew egalitarian norms as they ignored traditionalist critiques, offered direct support to more experienced colleagues and reconciled their own knowledge in new contexts rather than deferring to traditional hierarchical experience structures. Contrary to existing research on early career primary science teaching (Appleton 2003), the participants in this research displayed some signs of adaptive pedagogical repertoires and deep professional reflection that extended beyond student fun. One interviewee described a process of non-linear pedagogical pinballing that is often displayed by more experienced, expert science teachers (Mitchell et al. 2015). The most promising finding was that many of these early career teachers were electing to take on science leadership roles that would expand their influence beyond a single classroom. Seven of the interviewees had operated above and beyond the requirements of a typical generalist primary teacher. No conclusions can be drawn from the aforementioned trends, but the cumulative presence would be worthy of further investigation in the future.

There are at least four avenues for future research that arise from the findings and the methodological limitations above. First, while the argument for the durability of the participants’ self-efficacy beliefs is strong, a causal relationship has yet to be established between the two science subjects and
improved science teaching efficacy beliefs. Experimental research with a control group is needed to extend the research beyond covariance to causality. Second, research needs to explore the teaching practices of the graduate teachers in a tangible, objective manner. The reported teaching practice is limited by interview response bias and the self-selection surveying. The long-term research goal should be to determine what impacts the graduate teachers’ science teaching efficacy beliefs and practices have on their students. The research presented in this paper represents an incremental, but important, step into connecting the tertiary science education research with other stakeholder groups in science education. Third, meta-research should be conducted in the recruitment and sampling of inservice teachers. Preservice teachers, by virtue of proximity, are an easier group to sample sufficiently. The respectful, ethical use of social media sampling presented in this paper could serve as a model for increasing participant rates for inservice teachers. At the very least, researchers should begin to discuss their own sampling techniques and procedures in greater detail in order to assist others to traverse the gap between preservice and inservice teaching. In conclusion, school science cultures should be the explicit focus of research moving forward. This is an area that is often touched on indirectly but has not yet been fully explored. The research presented in this paper only begins to explore this crucial and rich area research domain. More research is needed to explore school science cultures in greater depth and across different contexts.
References


Connective Statement Five

The previous publication “From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university” (Deehan, Danaia & McKinnon, 2016) explored the transition of a group of preservice teachers to inservice status. A group of 82 graduate primary teachers, who had experienced the science program (SC108 and SC308) described and assessed in the second, third and fourth papers, responded to the STEBI-A instrument. A further 10 graduate teachers participated in semi-structured interviews. The quantitative results showed the graduates’ science teaching efficacy growth, experienced during their undergraduate science education, remained durable after they had transitioned into inservice teaching status. Deeper analysis showed that participants’ outcome expectancies declined while the personal science teaching efficacy beliefs increased. Cross-triangulation with semi-structured interview data suggests that these early career primary teachers may have shed their idealistic views on science teaching, yet shown confidence in their own abilities to teach science effectively. The participants’ school contexts had a combination of negative and positive influences on the reported science teaching practices of the respondents. Conversely, the respondents indicated that their tertiary science education was an overwhelmingly positive influence on their science teaching. The combined influence of graduates’ high science teaching efficacy beliefs, tertiary science experiences and in-school support appeared to instil them with the resilience needed to overcome hindrances (i.e., time, resources, low science priority). In fact, many graduates were engaging in positive practices such as undertaking science leadership roles, supporting colleagues, acting as
specialist science teachers and seeking out professional development opportunities.

To complete the doctoral dissertation with the previous publication would certainly have provided a worthy conclusion to the narrative and indeed this was the original intention. However, while the clearly contextualised research exploring a group of early career primary teachers’ journey from inservice to preservice status would have filled the specified gap within the literature, it could create a false sense of completion. The reality is that universities, schools and the societies within which science programs exist are constantly shifting. In the case of this doctoral dissertation, as the research was being conducted the tertiary institution underwent a shift towards online modes of education. This raises the dual need of progressing research forward into new, worthy directions whilst ensuring prior work and achievements remain valid and relevant. Thus, the next publication describes and evaluates the transition of the SC308 subject from a face-to-face to an online, distance mode of delivery.

The next publication “A model for the creation of cooperative e-learning spaces: Teaching early childhood and primary preservice teachers how to teach science” (Danaia & Deehan, 2016) describes the adaptation of the on-campus SC308 subject, as researched in publications two, three and four, to an online format. A model for the creation of a cooperative online learning environment is presented and evaluated through a mixed methods action research project. Survey, STEBI-B, online analytics and subject evaluation data were collected from two science curriculum studies courses over the course of a single semester in 2015. The first course was delivered entirely online. The second course received the same online delivery supplemented
with fortnightly face-to-face classes. A modified, reflective pre-post STEBI-B administration was adopted to both avoid the inconsistent sampling potentially arising from the geographical disparity of the population and the address the shift towards examining student perceptions of STEB growth. Despite beginning the semester with mixed attitudes towards science, the participants showed high levels of engagement, displayed growth in their science teaching efficacy beliefs and reported satisfaction with their education experiences, after extensive engagement and interaction with the different elements of the online learning environment. There is some evidence to suggest the approaches to tertiary science education presented and evaluated in this doctoral dissertation can be adapted to suit contextual changes that may occur in the tertiary sector.
Publication Six

A model for the creation of cooperative e-learning spaces: Teaching early childhood and primary preservice teachers how to teach science

Publication six has been publish in the online Fusion Journal. Language, formatting and referencing have been altered to suit this platform.

The candidate has made partial or full contributions in the following areas:

- Research Conceptualisation
- Data Collection
- Data Analysis
- Manuscript Drafting
- Manuscript Editing

An online version of the sixth publication can be accessed here -

A Model for the Creation of Cooperative e-Learning Spaces: Teaching early childhood and primary preservice teachers how to teach science.

Authors: Lena Danila and James Deehan, Charles Sturt University

Abstract

In this article, we describe how we have translated our face-to-face teaching of a science curriculum subject in to an e-learning environment that provides preservice early childhood and primary teachers with opportunities to practice how they would program for, and teach, science in a school setting. Many of the preservice teachers who enter our subject possess negative attitudes toward science, display low personal science teaching efficacy and lack confidence in the subject area. In an attempt to combat these issues, and to conceptualise our practice in an e-learning setting, we situate our preservice teachers in an online, cooperative learning environment in which they engage with the learning experiences that directly feed in to the assessment tasks. Through asynchronous and synchronous interactions with the teaching-team and each other, they begin to develop their confidence and competence in the teaching of science.

We present a model for the creation of cooperative e-learning spaces. The strategies and approaches we implement may also be useful in the professional learning of in-service teachers, other practice-based professions and, in the orientation of students to university.

In this exemplar, we draw on our experiences in two implementations of the subject to illustrate how we use the online tools afforded to us to generate a practice-based approach to the learning and teaching of science. We outline the action-research we are undertaking to inform the future implementation and iterations of the subject, identify the issues confronted, and, share our preservice teachers’ experiences in the subject based on the questionnaire, reflection and evaluation data we have collected. In the discussion, we consider the changes to both the subject design and e-learning environment that can be made based on the evidence collected from the action research. Broader implications for online tertiary education and future research are also discussed.

Introduction

There has been a considerable push to establish effective e-learning environments at the tertiary level (Johnson, Adams & Cummings, 2012; Johnson, Adams Becker, Cummins & Estrada, 2014). It has been argued that education has lagged behind other fields in the use of Information and Communication Technologies (ICTs) to enhance both the productivity and efficiency of practice (Larson & Vincent-Lancrin, 2005). The issues do not necessarily relate to the use of the ICTs, but rather the lack of core change to the processes of teaching (Keifh, 2015). This paper presents a model for tertiary e-learning that aimed to improve learner outcomes through the use of ICTs to promote student-centred active learning.

New e-learning needs to be considered as conceptually separate from the old model of distance education. During the earlier period of transition from print media to e-learning for distance education, there was a misconception that due to the multimodal affordances of ICTs constructivist learning would occur innately (Garrison & Anderson, 2003; Harasim, 2000). Without deep pedagogical consideration e-learning can resemble the more passive distance education models that have preceded it. McLaughlin and Lee (2010) argued that the use of ICTs in online environments need to be varied, personalised and supported to ensure that self-regulated learning can occur. The e-learning educational model described in this paper adopted various ICTs with clearly articulated standards for engagement and assessment achievement. The students were free to construct their own learning pathways with the available ICTs in the knowledge that their formal grades were tied to the assessment products rather than arbitrary processes. In order for students to construct their own learning pathways their own beliefs about the nature of learning needed to be
addressed explicitly within the e-learning model.

Student-centred learning in e-learning environments can be hindered by students' beliefs about teacher-centred learning (Westberry & Franken, 2012) and asynchronous learning experiences (Rockinson-Szapkiw & Wendt, 2015). According to Rockinson-Szapkiw and Wendt (2015) tertiary students with access to both synchronous and asynchronous online educational experiences showed better perceptions of online social presence, cognitive presence and teacher presence than those students who only utilised synchronous modes of communication. It would seem that access to a diverse array of scaffolded resources and strong expert teacher presence is needed to facilitate student-centred e-learning.

The call for integration of ICTs and development of e-learning environments that promote student-centred learning has grown within the Australian tertiary context. In 2014, the New Media Consortium, in collaboration with Open Universities Australia, released a national report on the technology outlook for Australian tertiary education. The report stated that online student-centred learning (i.e., flipped classrooms) needed to be adopted by tertiary institutions within a year. It was also acknowledged that scaling teaching innovations and keeping education relevant were barriers to establishing e-learning environments. The research presented in this paper explores the transition of an effective on-campus primary science subject to an e-learning format.

Science teacher education is a domain with a rich tradition of innovative pedagogical approaches. Many researchers have managed to successfully improve science teaching attitudes, capacity and content knowledge. Pedagogical innovations such as cooperative learning (Palmer, 2006), practical science teaching experience (Mulholland, Dorman & Odgers, 2004) inquiry learning (Leonard et al., 2011) and problem-based learning (Loganwell, 2009) have shown to improve student outcomes. The overwhelming majority of tertiary science education courses reported in the literature describe on-campus, face-to-face delivery of subjects. Some initial strides have been made to transfer science education subjects to online delivery models. Slater, Slater and Shaner (2008) incorporated interactive online learning modules as supplementary learning tasks that allowed students to complete more open-ended inquiry tasks during face-to-face workshops. The preservice teachers showed improvements in content knowledge, pedagogical understanding and science teaching efficacy. Such blending of online and on-campus approaches may be a valuable step in the transition from face-to-face to e-learning environments. Hasuvelo and Lozakowski (2010) progressed the literature further by separating on-campus and e-learning modes of delivery. The course required students to work collaboratively to design a science curriculum project over the course of the semester. The e-learning students were provided with group wikis and online forums in lieu of the face-to-face tutorial meetings offered to the on-campus cohort. The distance and internal cohorts both showed statistically significant increases to their personal science teaching efficacy beliefs. In fact, there was no significant difference between the groups, suggesting that there has been a successful transition from on-campus delivery to an e-learning environment. Online and blended modes of delivery are explored in this paper.

The purpose of this paper is to describe how we have translated our face-to-face teaching of a science curriculum subject into an e-learning environment that provides preservice early childhood and primary teachers with opportunities to practice how they would program for, and teach, science in a K-6 school setting. A key challenge was facilitating student-centred learning and practice-based experiences in an e-learning environment as we tried to overcome barriers of distance, time and students' expectations of distance education. We outline the action-research we have undertaken within the subject and draw on our experiences in two iterations of the subject to illustrate the subject design. We identify the issues confronted and share our preservice teachers' experiences in the subject based on the questionnaire, reflection and evaluation data we have collected. The discussion identifies broader implications for the design and implementation of future tertiary education subjects delivered in an e-learning environment.

**Subject Description**

At the start of the University year, we were charged with creating an e-learning environment for a science curriculum method subject that mirrors the outcomes and successes of the previous internal (face-to-face) deliveries. There were seven student learning outcomes identified for this subject. This meant that by engaging with the subject and
successfully completing the assessment tasks, students should be able to: employ a range of instructional and collaborative learning strategies in the science curriculum area; develop a science unit of work (curriculum or program of work to implement with students); use a range of diagnostic, formative and summative assessment; demonstrate skills in the use of technology; differentiate student learning; apply their understandings of content in the science curriculum; and, incorporate skill development into science learning experiences.

The model presented in figure 1 shows how the preservice teachers were scaffolded to participate in student-centred, cooperative learning in an e-learning environment. The large circle in the centre of the diagram represents the e-learning environment. The students had access to synchronous and asynchronous tools to connect them to the practice-based, cooperative learning environment. The variety of ICTs allowed the students to construct their own learning and communication pathways, thus allowing for the flexibility of e-learning to be maintained whilst constructivist, cooperative learning opportunities were fostered. The dotted arrows denote the non-linear nature of the learning within the subject as the students moved between individual and cooperative learning activities both within and beyond the e-learning environment. The two parallel lines in the centre of the diagram represent the intended learning pathway. While the students had control over how they chose to enter the PBL Cooperative learning environment, a combination of clear standards, ongoing instruction and assessment ensured that the students met the defined learning outcomes for the subject. Action research and teacher presence were direct and ongoing aspects of the core learning pathway. The dotted arrows connected to the teacher show how action research and student feedback informed the design of both the e-learning environment and the core learning pathway. This ensured that the e-learning environment would continue to evolve and adapt to students’ needs both within and across iterations of the science subject. The following paragraphs provide additional detail on how the science subject was delivered.
Our approach to ensuring our students achieved these outcomes was to place them in a project-based scenario where they were required to work online in a cooperative learning environment in which they engaged with the content and learning experiences that directly fed into the assessment tasks. By using the technology afforded to us through our learning management system, we attempted to mirror how we had previously taught an equivalent science curriculum subject that was delivered internally using the traditional face-to-face mode (McKinnon, Danaia & Deehan 2015 – Under Review).

At the start of session, we randomly assigned our preservice teachers to online learning groups comprising four students per group. We provided them with a project-based scenario where they would be working as a group of teachers to develop a class program (unit of work) for the science curriculum area. This reflects what typically happens in a primary school context, where teachers often work together to create their class program for the school term.

Within the online groups, we enabled a number of tools that students could use to communicate, share and collaboratively work on tasks in either a synchronous or asynchronous fashion. The tools included: a file exchange; blogs; discussion boards; group tasks; wikis; and, a group email function. While we gave our students instruction on the use of each tool, how groups used these tools was left to their discretion. The most popular tools were the group wikis for shared editing and the "Group discussion board" for asynchronous communication. Several groups communicated beyond these parameters via Skype, Facebook, phone calls and some even organised face-to-face meetings. We, the teaching staff, had access to all online groups and students became aware of this as we interacted
with them and provided them with formative feedback at certain stages of the semester. Individual students only had access to their online group. If they wanted to communicate with the rest of the cohort they could use a general discussion forum available in the main area of the subject site. Adobe Connect software was used as a synchronous learning tool that allowed the students to communicate with academic staff and other students in more structured learning spaces.

During the first six weeks of the subject, students learned how to work collaboratively to develop an inquiry-based science curriculum that incorporated the 5Es teaching and learning model (Bybee, 2014) and a range of instructional strategies. The 5Es is a constructivist, inquiry-based instructional model that actively engages students in their learning (Skemp & Pears, 2012). The model is divided into five distinct phases that can occur both within and across science lessons; the phases are Engage, Explore, Explain, Elaborate and Evaluate. In designing learning experiences for their curricula, students also had to apply their knowledge of the NSW K-10 science syllabus content (NSW Board of Studies, 2012) and the different assessment strategies that could be employed.

To help scaffold our students learning of the subject content we provided them with access to four online learning modules. The modules provided the students with essential information on a variety of topics, these included, but were not limited to: the nature of science, science teaching pedagogies and syllabus navigation. Embedded within the modules were movies modelling different instructional strategies used in the teaching of school science. The modules also comprised a number of tasks they engaged with both individually and collaboratively on the relevant Module discussion forum. To complement and extend their learning of the content they were covering within their groups, coupled with the module work, we also held weekly online sessions using the aforementioned Adobe connect software. The online sessions were recorded for those students who could not make the set time. This served the dual purpose of creating both a synchronous learning experience and an asynchronous resource.

The groups were organized and scaffolded to assist the students to share their concerns with each other. A non-threatening learning environment was created where they could establish rapport with each other. We gave them weekly tasks and required a weekly minimum standard where students had to make at least one meaningful contribution to their online group areas per week for the first half of the semester. This standard allowed for group communication to be fostered whilst still maintaining the flexibility afforded by distance education. We monitored students’ progress throughout this six week period.

**Subject Assessment**

The collaborative unit of work accounted for 60% of their marks within the subject. There were specific group components that were awarded a ‘group’ mark worth 15% in total. We found this provided the incentive for collaboration without overwhelming the students. It also drove the need for each of them to be individually accountable for their sections of the unit of work. We were instantiating one key principle of cooperative learning. The intention was to mirror professional practice, as the students worked on broader, overarching tasks together and completed the more complex tasks individually. In the process, they were employing a number of cooperative learning strategies such as jigsaw, brainstorming and think-pair-share. That is to say, they were gaining experience in using some of the strategies they will later implement in a classroom setting.

The second assessment task required students to create a digital learning resource that would facilitate the learning of a science concept and/or skill in an authentic way as part of a learning activity within the unit of work they constructed for the first assessment task. In this sense, the assessments were constructively aligned and carefully designed to enable our students to engage in the deep reflection and practical thinking that is required for effective science teaching. In designing the digital resource, our preservice teachers had to consider the differentiated learning needs of the pupils who would potentially be using the resource.

Groups were given the opportunity to receive formative feedback from us two weeks before the submission of the first assessment task. Feedback was delivered via the group areas. By doing this, we were modelling how teachers...
provide formative feedback to their students. It also allowed our students the opportunity to reflect and act on this feedback before having their assessment task summatively assessed. Essentially, this provided another avenue for formal student-lecturer communication that reduced the gap between online and distance deliveries. A list of suggested tasks was posted weekly to ensure that students maintained steady progress towards the completion of the assessment items. The tasks were presented as optional to allow for personalised learning and student agency. Through some of our Adobe Connect sessions, we provided our students with the opportunity to assess an assessment task. We supplied examples of different digital resources and asked them to first conduct a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis on the resources and second, use the marking rubric we had supplied for this assessment to assess the task. We were providing them with an opportunity to learn about assessing a work sample by actively doing it.

Research Methodology

Underpinning our subject design was an action research framework where we collected both qualitative and quantitative data throughout the 14-week science subject from our two cohorts of preservice teachers in a reactive fashion (Stringer, 2007). This allowed us to make informed decisions about our teaching within the subject. We also monitored the online tool usage and student interactions in an attempt to track student engagement with the subject. Ethics approval for the research in this paper was gained through our University’s Ethics in Human Research Committee as part of an ongoing action research project into the delivery of our science curriculum subjects (Protocol Number 2006/122). In the sub-sections below we share results from some of the data we have collected. In keeping with the action research framework, data have been organised in relation to when they were collected across the semester in order to create a descriptive narrative. The qualitative and quantitative data collection methods are described as they appear within the results to develop an immediate, narrative structure to support the action research design.

Participants

The science curriculum subject was delivered to two different cohorts of students through our online learning management system. One cohort was purely online (cohort 1). They were Distance Education students enrolled in a Bachelor of Teaching. These students had previously obtained an undergraduate degree in another discipline and were looking to change career paths into teaching. Cohort 1 comprised 89 preservice teachers. The second cohort comprised internal students studying the subject via distance education (cohort 2). These students were third year undergraduates enrolled in a Bachelor of Education (Early Childhood and Primary) Degree. There were 141 preservice teachers in cohort 2. For the purpose of this paper, we will refer to the two cohorts as cohort 1: online and cohort 2: blended. Both cohorts were studying the same subject. The subject was run in a parallel fashion where the cohorts had separate e-learning sites and different subject coordinators yet the students accessed the same information, received the same educational experiences and completed the same assessment tasks. The data reported on in the results below has been taken from opportunistic sampling of both cohort groups.

Results

Start of semester: Attitude toward science survey

During the first two weeks of session, we asked students to complete the Your Attitude Toward Science survey (Koch, 2013) so that we could get a sense of their feelings, thoughts and experiences in relation to science. The survey comprised 20 rating scale items where students had the option of selecting strongly agree, agree, no opinion, disagree or strongly disagree. Figure 2 below presents the pattern of student responses to each of the 20 items.
Most students (85%) felt that science was useful for the problems in everyday life. Just over 90% of students who responded to the survey revealed that they enjoy hands-on practical activities in science. Over half of the respondents enjoy watching science programs and talking to people about science. Despite this enjoyment factor, more than half indicated that science was difficult for them. It was interesting to note the percentage of students who selected no opinion in response to a number of the questions. Overall, these responses highlighted for us that students could see the value and benefits of science, enjoyed aspects of it but may have had some reservations about how they might perform within a science subject while a number were yet to still form opinions. We were left wondering how our online delivery of a very practical-based subject would inform their opinions.

Students worked in cooperative learning groups during the first six weeks of the session. In an attempt to overcome students’ reluctance to work in a group situation (Hansen, 2006; Kellab & Mullan, 2007; Pfaff & Huddleston, 2003), we provided them with a justification as to why they needed to learn to work in a group context. We made a direct link back to their future profession in schools where they would need to have the skills to work with not only other teachers, but parents, community members and other relevant stakeholders. They began to see the purpose of working in a group and why we wanted them to experience this.

Together they developed a variety of professional science teaching skills as they developed their curriculum products for the first assessment task. Such complex, social-constructivist learning is inherently difficult to monitor and evaluate (Juan, Daradouris, Faulin & Xhafla, 2005). With so many aspects and interactions, both within and beyond the subject design, it was difficult to find a clear measure for the success of the group learning. Due to the popularity of the test, participation in group forums was analysed as an indicator of group activity for cohort 1. Across all forums within the subject activity levels were high. A total of 1786 posts were made during the first half of the semester, equating to
296 posts per week. Participation in the group discussion forums also exceeded the minimum standards. A total of 1462 forum posts were made across 27 group forums for an average of 53.8 posts per group.

The numbers of group forum posts were assessed in relation to the number of active members within each group. This allowed for mean individual levels of participation to be compared to the minimum standard of one meaningful contribution per week. The average student was contributing to his/her group discussion 2.9 times per week, nearly triple the minimum standard. Only two of the 27 groups failed to reach the minimum standard. In fact, 66% of the groups had more than doubled the minimum requirement for weekly individual interactions. While the number of posts only provided a limited insight into the overall quality of the cooperative learning, it certainly showed a positive trend of student engagement.

Mid-semester: Harvard one-minute feedback paper

During the two-week mid-semester break, we asked students from both cohorts to complete a Harvard one-minute feedback paper based on their experiences within the subject during the first half of the session. The one-minute Harvard paper is a formative feedback instrument. It comprised five items that included: what worked for them; what did not work for them; three things they learned; three things they need to know more about; and, list five words to describe their stream of consciousness about how they felt in relation to the first half of the semester (Chizmar & Ostrowsky, 1998).

There were 39 preservice teachers who elected to complete the Harvard one-minute paper. Overall, those students reported positive feelings towards their experiences in the subject during the first half of the semester. In response to the “What worked for you?” question, the overwhelming majority of respondents (74%) valued the learning opportunities afforded by the weekly Adobe Connect sessions. Quote such as “I liked the opportunity to ask questions during tutorials (S1)” and “The online meetings discussing the assignment were fantastic (S2)” highlight students’ positive response to these online sessions. “The ability to ask questions and get answers immediately made the task much more manageable and enjoyable (S3)”, shows that the students valued the inclusion of synchronous learning tools and opportunities. In fact, one student noted the scarcity of such experiences in his/her experience of distance education “I welcomed the weekly meetings; first time in a decade of study that I have had this opportunity (S4)”. Other elements that were deemed to have educational value by students were the group wikis, formative feedback and online learning modules. Clearly, they had responded positively to the inclusion of synchronous and asynchronous learning tools to facilitate cooperative, practice-based learning in the e-learning environment.

In relation to the stream of consciousness about the first half of the session 115 words were classified as positive while 21 words were classified as negative. Words such as ‘challenging’, ‘interesting’, ‘stimulating’ and ‘productive’ were used frequently, suggesting that the students had engaged deeply with the e-learning environment. Based on this, it could be suggested that the students were not simply ‘having fun’, rather they valued the academic rigour of the subject.

End of semester: Reflective STEBI-B

The science teaching efficacy beliefs of the students were assessed at the end of the semester as a way of determining whether the subject was aiding the students in meeting the core objectives. Teaching efficacy beliefs have been shown to affect resilience (de Laat & Wetzels, 1995), pedagogical choices (Tschannen-Moran, Woolfolk Hoy & Hoy, 1998) and even student achievement (Tschannen-Moran & Barr, 2004). The science teaching efficacy belief instrument B measures the personal science teaching efficacy beliefs (PSTE) and science teaching outcome expectancies (STOE) of preservice teachers through a series of Likert items (Bleichner, 2004; Enoch & Rigs, 1996). The STEBI-B was administered in reflective pre/post form. This reflective delivery has been adopted in both preservice (Cartwright & Atwood, 2014) and in-service (Ulmer et al. 2014) science teaching research. Within the action research approach, the reflective pre/post administration of the instrument served the dual purpose of assessment science teaching efficacy growth and students’ perceptions of their own growth over the course of a science intervention. A total of 23 students from cohort 1 elected to complete the reflective pre/post STEBI-B survey. Cohort 2
were not given the opportunity to complete this survey as they had commenced professional experience at the end of the semester. Analysis of the STEBI-B data collected within this research project showed that both the PSTE (Cronbach’s a = 0.781) and STOE subscales (Cronbach’s a = 0.709) were both reliable.

A Multivariate Analysis of Variance (MANOVA) was conducted on the reflective pre- and post-test STEBI-B data to determine if there was significant growth on the subscales over time. Table 1 shows the output from the STEBI-B MANOVA. There was a significant main effect due to occasion of testing (F(1,122)=42.44, p<0.0001). This indicates that the STEBI-B changes that occurred within the participants over the course of the semester were statistically significant. There was no significant main effect due to the STEB variable (F(1,122)=3.248, p=0.085). That is to say, there was no significant difference between the PSTE and STOE scores of the participants. This is a promising finding as much of the research in this area shows that the STOE subscale often lags behind the PSTE subscale.

Table 1: STEBI-B MANOVA

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEB</td>
<td>90.011</td>
<td>1</td>
<td>90.011</td>
<td>3.248</td>
<td>0.085</td>
</tr>
<tr>
<td>Error(STEB)</td>
<td>609.739</td>
<td>22</td>
<td>27.715</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion</td>
<td>493.141</td>
<td>1</td>
<td>493.141</td>
<td>42.44</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error(Occasion)</td>
<td>255.609</td>
<td>22</td>
<td>11.619</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occasion * STEB</td>
<td>51.750</td>
<td>1</td>
<td>51.750</td>
<td>6.658</td>
<td>0.017</td>
</tr>
<tr>
<td>Error(Occasion*STEB)</td>
<td>171.000</td>
<td>22</td>
<td>7.773</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Both the PSTE and STOE subscales showed large increases with Cohen’s D effect sizes of 1.367 and 0.991 respectively. Such results are also noteworthy within the broader base of the STEBI-B literature. Across the 25-year history of the STEBI-B instrument the PSTE and STOE effect sizes found within this action research project are amongst the 10 largest effect size increases. The PSTE size would be the 9th highest reported growth and the STOE effect size would be the 4th largest pre-to-post increase. These trends should be taken with caution as the respondents had the benefit of hindsight in their responses. Nonetheless, the STEBI-B data is evidence that the students showed greater science teaching efficacy after they completed the online science subjects.

Subject Evaluation Comments

At the completion of the semester, all students across the university were afforded the opportunity to provide open, de-identified feedback about their subjects. The open comments submitted allowed for open insight into their experiences in the online and blended e-learning science subjects. The students made thoughtful and detailed responses to the first open question “What about this subject did you find most helpful in your learning?” A total of 48 students across both cohorts elected to provide data on this item. Figure 3 shows the frequency that each positive theme emerged within the feedback. The qualitative data show that the students valued the communication pathways that were established in the e-learning environments. This can be seen in the prominence of the online meeting (31), student/lecturer communication (20) and student/ student communication (12) themes. One student summarised his/her relief that the online learning environment had finally helped him/her feel like an active member of a learning community:

"James gave us a lot of support. He organised structures so we had audio and visual of him, and a chance to interact, both in real time and with an open invitation to send emails. I felt like I was a part of..."
something, instead of being a remote student that could be attended to or not. I find it hard that each subject is a distinctive experience, without even continuity from corridors, classrooms and cafeterias, but this time there was an effort to include us. (S5)

Despite the subject focuses framing of the “What worked” question, Lecturer (17) theme emerged as a central positive theme. This represents the core concepts of constructivism that have underpinned educational principles for decades (Vygotsky, 1977). The need for human connection needs to be considered within online education and the subject described in this paper presents a viable model for fostering such connection. The importance of people can have considerable implications for tertiary education. This is reflected in the quote below:

“Online chat sessions with Lena. These were fantastic. The nature of the assessment tasks meant that studying the subject by distance was difficult. The opportunities to engage in online meetings with Lena each week were wonderful opportunities to gain a better understanding of the subject content and assessment requirements. Without those sessions I believe that my performance in the subject would have been severely affected. (S6)”

The varied integration of assessment throughout the subject was valued by members of both cohorts. Concepts such as ‘Feedback’ (8), ‘Assessment’ (10) and ‘Relevance’ (5) combine to show that students were able to see how the subject reflected the requirements of professional science teaching. This also shows that the students understood the intended learning pathway at the centre of the e-learning environment. The ongoing support, supplemented by formative and summative feedback, and the relevance of the assessment tasks beyond the subjects appeared to help the students to make connections between the tertiary context and the profession which they were training to enter. This can be seen in the following quotes from two different students:

“The subject provided authentic assessment tasks which are relevant and useful when prac teaching. (S7)”

“The assessment tasks were directly relevant to what we will be required to do in the future, and the feedback given was helpful. (S8)”
The preservice teachers were invited to give an honest appraisal of the elements of the subjects that were 'least helpful' in their learning. Figure 4 shows the frequency that each negative theme was cited within the open ended, written submissions. Overall there were fewer negative responses than positive responses to the science subject. The students' negative comments about assessment (14) and student/student communication (6) refer to their poor responses to the group work that was embedded in the first assessment task. Students bemoaned the difficulty in establishing reliable communication patterns with other students both within and beyond the confines of the e-learning environment. However, despite their concerns, it was evident in the student responses that they understood the necessity and value of working collaboratively. Their negative reporting of group work may be a reflection of their past, individualistic learning experiences within subjects. Perhaps the issue remains with fostering communication pathways rather than student aversion to group learning. Certainly, the following students saw the value of collaborative learning despite their criticisms:

"Working as a group in assessment one, gave the opportunity for peers to have other ideas and conversation about the topic. (S9)"

"In reference to assessment 1, the allocation of groups meant that all other members who I collaborated with were extremely unreliable and unwilling to participate. This was very stressful but I can see that it also taught me a lot. (S10)"

The evaluative comments revealed a tension between students' traditional views of distance education and their new experiences within a cooperative, student-centred e-learning environment. It appears as though the absence of synchronous means of peer communication hindered the learning process and production of assessment items. When these trends are considered along with the emergence of the negative Distance Education theme (7), there is evidence that students may be holding onto traditionalist, teacher centred views of education. This may also be supported by some of the negative reports of group work. The singular presence of the distance education theme and blended delivery of the subject may be an indicator of deeper issues with mixed modes of delivery within single subjects. The tension emerges from their negative reports of the modules/ readings (11). While they may still be holding onto more traditional views of distance education, it was clear that they began to value the cooperative and more active components of the e-learning environment. This is reflected in Figure 3 where there was a greater positive response to the online meetings (32) in relation to the modules and readings (2).
Time spent in the E-learning environment

We investigated the relationship between the time spent in the e-learning environment and the final grade achieved by each student. Our analysis revealed that there was a statistically significant relationship between these two variables. That is to say, the more time a student spent in the e-learning environment the higher the grade awarded. It should be noted however that, across both cohorts, the correlations between the variables were weak-to-moderate. This prompted us to further investigate students’ time spent in the e-learning environment. Online activity reports allowed us to track how long each course participant was logged into the online learning environment. While this measure does not account for the complexity of learning within the broader subject, it does provide an insight into the level of online engagement for each student. Within the blended subject (cohort 2) students spent an average of 15.85 hours logged onto the online learning environment across the three-month semester. The mixed delivery of this subject may have skewed this data because a number of students had access to on-campus learning activities to supplement the online subject delivery. One student spent a staggering 164.22 hours within the online learning environment. The students enrolled in the parallel online subject (cohort 1) spent an average of 31.52 hours logged into the online learning environment. Across the 12 active teaching weeks of the semester this equated to 2.6 hours of direct subject engagement per student per week. From a simple time perspective, this is very close to the direct course contact expected within an on-campus subject delivery. Typically on-campus subjects offer a single one-hour lecture and a two-hour tutorial. These analyses are somewhat diminished because factors such as off-line learning, specific activities within the online learning environment and time spent away from the computer. Nonetheless, there is strong evidence to suggest that our e-learning science education model is making tangible progress in diminishing potential engagement gaps between on-campus and distance modes of learning.

Summary of Results

In relation to the data we collected and tracked throughout the session, we cannot establish a definitive link between student achievement and course participation. We can note, however, that engagement as measured by time spent in the e-learning environment was close to the expectation of an on-campus subject: 2.6 hours versus 3.0 hours. Our university does not have an on-campus attendance policy. So, in essence, our students who were in the e-learning setting may have even had more contact or engagement compared with their on-campus counterparts. We can also note from our students’ feedback that they valued the academic rigour of the subject. One student sent the following in an unsolicited email:

"Thanks for all your guidance through this unit [subject], it has been one of my more challenging ones – although I did 3 unit science at high school, certainly a different approach these days :). Talk about having to think about what I bring with me to the classroom! (S9)"

In the subject evaluation data, there was evidence to suggest that there is a tension between students’ conceptions or expectations of distance learning and the reality of studying in the e-learning environment. Despite some of the limitations and problems we encountered, our subject design appears to have professionally engaged many as highlighted in the following thank you from one of our students:

"I must say a huge thank you to James and yourself [Lena]. This has really been one of the best and well organised subjects I’ve completed in 16 months with [this institution]. It has been a truly enjoyable subject. (S10)"

Discussion

In this article, we have described how we have conceptualised our practice of teaching preservice teachers how to
teach science in an e-learning environment and reflected on how our students interacted with this environment. There was evidence to suggest that our approach generated a community of inquiry. We required students to work collaboratively for their first assessment task and used the digital technologies afforded to us to create the cooperative learning groups. Doing this facilitated the co-generation of knowledge for the first assessment and established learning connections between students.

The synchronous interaction between students and teaching staff was of critical importance as it provided a means through which genuine relationships could be established between students and staff. This has major implications for the delivery of online subjects. It highlights that the e-learning environment should facilitate teacher presence rather than replace it. It also raises issues around the staffing of online subjects and the commitment needed to maintain an online presence. With the increased casualisation of academic teaching loads (Byron & Barnes, 2000; Kimber, 2003), online teaching presence is a factor that must be considered in sessional workloads. In reconceptualising our practice, we also need to consider our commitment to synchronous interactions and perhaps reconsider our more traditional working hours. The majority of students within our subject worked during the day. This meant we had to be flexible and offer evening synchronous sessions to cater for the needs of our students.

The cooperative e-learning model we present appears to be a viable and effective way of transitioning tertiary education subjects from face-to-face to online modes. The variable communication methods, both synchronous and asynchronous, allowed the participants to choose the ways that they entered the designated learning pathway. The qualitative and quantitative data presented in this paper shows that the preservice teachers who utilised the e-learning environment to assist in the achievement of the learning outcomes showed increased science teaching efficacy beliefs, high levels of subject engagement and high levels of satisfaction with their educational experiences.

One element that was hard to replicate within the e-learning environment was providing our students with the opportunity of a school-based teaching experience within the science curriculum area. Embedding a school-based experience in future e-learning versions of the subject is one aspect we would like to continue to explore.

The action research presented in this paper can be used as a model for other practitioners to not only interrogate the design and delivery of a subject but to inform and refine future iterations of subjects. Ongoing in-subject action research is a realistic way of ensuring that tertiary students continue to receive adaptive, rigorous and satisfying education experiences. Despite the positive impact of the first iterations of the online science subject, the data collected over the first session were used to inform several changes to future iterations of the science subject. The weighting of the group component of the first assessment task will be reduced and separated in response to students' negative reactions to cooperative learning and traditional expectations of distance education. The single page report in the second assessment task will be replaced with an adapted and annotated lesson plan to both strengthen the connection to the first assignment and promote reflective teaching practice. The e-learning resource base will also be developed further to cover contemporary science issues in society, scientific reasoning, technical skills and group interactions.

There are a number of limitations to the action research described in this paper that have implications for future research. The action research approach, while appropriate, produced limited sample sizes due to time constraints and the opportunistic sampling of the target population. In future iterations of the subject, data collection methodologies could be imbedded within the e-learning environment and learning pathway to enhance response rates. Future research could compare traditional distance education approaches with cooperative e-learning environments. Another key step in this line of research would be to bridge the gap between on-campus and distance forms of science education. Such research could help to determine if cooperative e-learning can replicate the learning outcomes of face-to-face cooperative learning.

We encourage others working in this e-learning environment to adopt an action research framework to interrogate and inform their teaching and to monitor their students' learning and engagement. At the end of this action research cycle, we see our approach as being fluid, contextually bound and reactive to the needs of our students. The educational objectives of our subject inform our pedagogical choices and the tools we use within an e-learning environment. No
matter what delivery method (online, blended or face to face), subject design, teacher presence and students' needs should always be given deep consideration. Given this, should the discussion move from reconceptualising practice in an e-learning environment to conceptualising best practice for your current group of students?

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Discussion and Conclusion

A series of chapters, publications and connectives have been presented to provide a cohesive research narrative that has addressed the aims presented at the beginning of the thesis. This research project aimed to:

1. Determine how the science-teaching efficacy beliefs of both preservice and inservice primary teachers are represented within research literature and subsequently addressed through interventions.

2. Investigate the relationship between two complex, innovative and complementary science courses and the science teaching efficacy beliefs and science teaching perceptions of preservice primary teachers.

3. Investigate the science teaching efficacy beliefs and reported science teaching practices of former preservice primary teachers, who experienced the two complex, innovative and complementary science courses and who are now practicing inservice primary teachers.

The first aim has been met, as the first publication reviewed the STEBI literature to an unprecedented level of depth. We now have a fuller understanding of the varied research methodologies and approaches to tertiary science education which have been published in the STEBI literature base over the past 25 years. The second aim has also been fulfilled, as multiple forms of evidence have suggested that participation in a complex, innovative science program (SC108 and SC308) covaries with increases to preservice primary teachers’ STEBs. Evidence presented within publications two, three, four and indicated that the STEBs of preservice primary teachers showed statistically significant growth, even with different offerings, changes to
teaching staff and a move to an online learning format. Qualitative data presented in publications two, three and six indicated that participants of the science program had improved perceptions of science teaching, with reports of greater confidence, positive reactions to the courses and more desire to teach science in the future. The third, and final, aim has also been addressed.

According to evidence outlined in the fifth publication, the statistically significant levels of STEB growth reported during the science program (SC108 and SC308) remained durable after the participants had graduated and transitioned to inservice teaching status. Interview data suggested the graduates believed their experiences of the science program allowed them to overcome professional hindrances to deliver student-centred science lessons.

The contributions of this doctoral research extend beyond the three core aims. Each of the six publications stands alone as a meaningful and unique addition to the existing body of primary science literature. The following paragraphs will unpack the broader significance of each publication.

The first publication, “The Science Teaching Efficacy Belief Instruments (STEBI A and B): A Comprehensive Review of Methods and Findings from 25 Years of Science Education Research” (Deehan, 2016), used a deep meta-analytic approach to summarise and critique existing STEBI-B and STEBI-A literature in terms of both methodologies employed and results reported. A series of rigorous literature searches returned 140 (STEBI-B) and 107 (STEBI-A) articles, dissertations and theses which used the instruments to gather data. A review of this magnitude (257) and scope (25-years of research from 21 contributing nations) is, as of publication, unprecedented within the STEBI literature. Furthermore, the structural framework presented within this
publication can serve as a model for the systemic review of literature in other areas of research, in science education and beyond. As publication rates increase as platforms become more accessible, meta analyses will be needed to summarize and critique growing bodies of literature in order to ensure that research continues to have meaningful impacts.

The second publication, “The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model” (McKinnon, Danaia & Deehan, 2016), draws on evidence accrued through action research to describe and tentatively evaluate two innovative, complementary tertiary science courses. Both the SC108 and SC308 courses utilise more than twice the mean number of innovative practices reported per science intervention in the STEBI-B literature. The courses also represent a considerable shift away from the more transmissive and content heavy science courses that have been relied upon historically in the delivery of science education to preservice primary teachers (Baldwin, 2014; Bybee, 2014). The varied and complex use of innovative practices within the courses has been seldom reported within the literature. The use an action research framework to provide an evaluative and descriptive narrative is also a unique contribution to the literature. In contrast to most of the existing literature, where interventions are typically described broadly, this publication provides a detailed and replicable overview of two science courses; thus ensuring that the approaches outlined and evaluated can be transferred to new contexts. Additionally, the Interactive Educational Design Model (IEDM) frames the often vague and intangible construct of Pedagogical Content Knowledge (PCK) in a relevant and accessible way for researchers and educators.
The third publication, “A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice primary teachers” (Deehan, Danaia & McKinnon, 2016), presents the findings of two complementary, concurrent nested mixed methods case studies to investigate the tertiary science education (SC108 and SC308) of a cohort of preservice primary teachers over a four-year period. The longitudinal design of this research is a worthwhile contribution to a body of STEBI-B literature where simpler pre-post administrations of the instrument is the norm. The weekly STEBI-B administrations allowed for accurate tracking of participants’ STEBs as they undertook the different learning activities presented in the SC108 and SC308 course, thus allowing for some evaluation of the different practices, which comprise the courses. As of publication, this level of depth has not been replicated within the STEBI literature. While the durability of STEBs has been considered through longitudinal research in the past, the full 2-year delay period used in this publication is not yet commonplace. The reported durability of participants’ STEBs helps to build the argument that the science courses may be a vehicle for long-term improvement in primary science education. The larger means and growth rates reported on the STOE subscale also differentiate this research from the rest of the literature, where the STOE subscale almost always falls below the PSTE subscale in terms of mean score and growth.

The fourth publication, “A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice primary teachers” (Deehan, McKinnon & Danaia, 2016), reports on STEBI-B data collected within multiple case studies of preservice teachers who undertook the science program (SC108 and SC308), either partially or fully, during an eight-year
period (2007-2014). A total of 877 preservice teachers provided STEBI-B data on at least one occasion of testing. Both the eight-year period (2007-2014) and the sample size (877) are almost unparalleled within the STEBI-B literature. Such a comprehensive sample further strengthens the argument that the science courses (SC108 and SC308) covaries with statistically significant increases in preservice primary teachers’ STEBs, first presented in publication three. The aforementioned unique strength of the participants’ STOE relative to their PSTE is still evident in the expanded STEB dataset, which lends credence to the interpretation that the cohort, investigated in publication three, is a representative sample of the broader population. It should also be noted that the eight-year data collection period allowed for the instructor variable to be considered in a way not yet presented within the literature.

The fifth publication, “From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of primary teachers who have recently graduated from university” (Deehan, Danaia & McKinnon, 2016), presents the findings of a mixed methods research project, with a concurrent triangulation strategy, where data were collected from inservice teachers who had experienced the aforementioned science program as undergraduates. Data were collected via the STEBI-A instrument and semi-structured interviews with the express intent of assessing the durability of STEB changes recorded at university and openly exploring how the graduates relate their science education experiences with their early career science teaching experiences. Much of the existing STEBI literature has investigated the transition from preservice to inservice teaching status qualitatively (Soprano & Yang, 2013). The fifth publication is one of the few pieces of
STEBI research (e.g. McKinnon & Lamberts, 2014) to utilise the complementary nature of the STEBI-A and STEBI-B as a means to quantitatively investigate the preservice to inservice transition. This addresses a clear gap in the literature as issues reported with primary science students and teachers seem to conflict directly with the often-positive reports of tertiary science education programs. An interesting finding was the continued growth in the graduate teachers’ PSTEs. This is particularly noteworthy, as continued growth beyond science interventions has not been presented clearly within the literature yet. Indeed, much of the longitudinal research, still largely bound within the tertiary domain, focused on the durability of earlier gains rather than continued growth in the absence of treatment.

The sixth publication, “A model for the creation of cooperative e-learning spaces: Teaching early childhood and primary preservice teachers how to teach science” (Danaia & Deehan, 2016), describes an action research project used to evaluate the transition of the SC308 course from a face-to-face mode of delivery to an online mode of delivery. While some researchers have considered online learning within the STEBI-B literature (Haeusler & Lozanovski, 2010; Slater, Slater & Shaner, 2008), it has not yet become a major area of focus. The research presented in the sixth publication represents the start of a new, and necessary, direction for primary preservice teacher science education research as the online mode of delivery is the main focus. The action research framework and cooperative e-learning model show how traditional face-to-face science courses can be adapted to suit the needs of distance learners via online technologies. Indeed, there is some evidence to suggest that the successful outcomes of the SC308 science course (as described in publications two, three and four) may be, at least partially,
replicable in an online learning format. This adds to the ongoing argument that the science program is an effective, viable and replicable way of improving the science teaching efficacy beliefs of preservice primary teachers. The next section will use the evidence presented across the six publications to answer the research questions.

**Answering the Research Questions**

This section will present answers to the three research questions presented in this doctoral dissertation.

**Question 1**

- How are the science-teaching efficacy beliefs of both preservice and inservice primary teachers represented within research literature and subsequently addressed through interventions?

**Answer (Publication one).**

The science teaching efficacy beliefs of preservice teachers, as measured by the STEBI-B instrument (Enochs & Riggs, 1990), have been represented in a significant variety of compelling and worthwhile research projects. The instrument has been used as: a basis for deep qualitative interviews (Tosun, 2000); a means of assessing relationships between science teaching efficacy beliefs and other variables (Serin & Bayraktar, 2014); a way of assessing science education courses (Swar & Dooley, 2010); and even as: a way of assessing the cumulative effects of entire teacher education programs (Ginns, Tulip, Watters & Lucas, 1995). The reliability and validity of the STEBI-B instrument has lead its use as a basis for the development
of alternate efficacy instruments (Wilson, 2012). The body of literature appears to show a shift from identifying science teaching efficacy issues to rectifying previously identified issues. This is evident as there has been a trend towards rigorous research designs with multiple administrations of the STEBI-B instrument. In fact, multiple administrations of the STEBI-B instrument were used to obtain relevant statistical samples in 60% of the analysed articles.

Similar variation can be seen in how the STEBI-A (Riggs & Enochs, 1990) has been adopted within inservice science teaching research. A simple analysis of the literature in terms the number of STEBI-A shows a relatively even spread of research approaches, with 40% of research reporting one use, 23% reporting two uses and a further 37% reporting more than two uses of the instrument. The instrument has been used to: conduct deep case study research (Nafziger, 2008); target research participants (Ramey-Gassert, Shroyer & Staver, 1996); make comparisons with student variables (Saam, Boone & Chasse, 2000); explore relationships with science content knowledge (Lekhu, 2013); assess the influence of professional development programs (Nelson, 2006); and determine the durability of efficacious change (Sandholtz & Ringstaff, 2011). The STEBI-A has had, and continues to have, a lasting impact as a means of consistently measuring efficacy constructs in a field with inherently intangible variables. The STEBI-A has also played a role in the globalisation of science teacher research as nations such as China, Ecuador, The Netherlands and The United Arab Emirates have all contributed to the body of literature within the past five years. Researchers are making strides to capture
strong samples of inservice teachers as there was an average of 80 participants per research project. The average number of participants only dropped to 65 when the cross sectional and qualitative research was removed. There are still some issues with sampling for research designs with multiple STEBI-A administrations.

There is considerable pedagogical variation amongst the science interventions presented in the STEBI-B literature. Curriculum development (Logerwell, 2009), inquiry learning (Yang, Anderson & Burke, 2012), and in-subject practical experiences (Brower, 2012) are the most common pedagogical inclusions within the STEBI-B literature. ICT instruction (Slater, Slater & Shaner, 2008), links to professional experiences placements (Swarz & Dooley, 2010) and problem-based learning (Watters, 2007) were all conspicuously absent from the body of research. Educational designs with multiple innovative practices and deep collaboration beyond the immediate subject tend to covary with higher effect sizes on the PSTE and STOE subscales. Student centred approaches and practical science teaching experiences were used within the science interventions that produced the strongest growth in personal science teaching efficacy (Cooper, 2015; Palmer, 2006). Conversely, analyses revealed that there is no simple pedagogical solution to producing high effect size gains on the STOE subscale. This can likely can attributed to the varied, external locus of control and influence of the broader science teaching outcome expectancy subscale. The number of innovations used within science interventions appears to be a stronger predictor of STOE growth rather than the types innovations used. Yet, the simplification of content also
covaries with improved STOE scores (Ozdelik & Bulunuz, 2009; Palmer, 2006). Such dissonance between content and pedagogies in the research trends resembles the broader issues that are frequently mentioned in relation to the STOE subscale.

The practical needs of teachers appear to influence the pedagogical inclusions within the analysed science programs presented in the STEBI-A literature. Inquiry learning (Eshach, 2003), cooperative learning (Velthuis, 2014) and curriculum development (Haeusler & Lozanovski, 2010) were the most common pedagogical inclusions amongst the 76 coded science interventions. Each of the other innovations was represented within the literature at least once. The same teacher-centred, practical approaches were evident in the interventions that covaried with the strongest PSTE and STOE effect size gains (Kean & Enochs, 2001; Roberts, Henson, Tharp & Moreno, 2001). The mean effect size gain for the PSTE subscale (Cohen’s d = 0.57) was notably, if expectedly, higher than the mean effect size gain on the STOE subscale (Cohen’s d=0.40). Curiously, despite the aforementioned separation of the subscales, there were no clear key pedagogical differences between the top interventions in terms of PSTE and STOE growth. The absence of significant STOE gains throughout the STEBI-A literature more broadly, dilutes the comparison between the subscales in terms of pedagogical influence. There was a slight trend toward less complex program designs with fewer innovative practices. Perhaps clearer program designs account for the need of practicing teachers to balance their professional practice with participation in science professional development.
Concerted efforts are being made to overcome issues stemming from difficulty in accessing and supporting inservice teachers. Since 2010 8 programs have incorporated online elements as a means of supplementing traditional face-to-face deliveries (Sang et al., 2012).

**Question 2**

- Does preservice primary teacher participation in two complex, innovative and complementary science courses covary with improvement in science teaching efficacy beliefs and positive science teaching perceptions?

**Answer (Publications three, four and six).**

The evidence presented in publications three, four and six help to answer this question.

The evidence presented within this dissertation indicates that the SC108 course covaries with improved science teaching efficacy beliefs. The cohort, subject to the deep investigation presented in the third publication, showed highly significant increases to their science teaching efficacy beliefs as they completed the SC108 course (F(1,107)=42.85, p<0.001). Deeper analysis showed that the PSTE scores increased moderately (Cohen’s d=0.41), while the STOE scores showed larger increases (Cohen’s d=0.79). The more expansive STEBI-B evidence taken from additional cohorts, over an eight-year period, presented in the fourth publication appears to confirm these findings. Indeed, a MANOVA conducted on all full STEBI-B datasets collected from SC108 offerings (2007-2013) showed that there was a highly significant increase in participants’
science teaching efficacy beliefs ($F(1, 531)=246.727, p<0.001$). The growth rates reported on the separate subscales are dissimilar. The 534 SC108 participants (2007-2013) showed a moderate Cohen’s $d$ effect size increase of 0.49, which is well below the STEBI-B literature mean of 0.83, as outlined in the STEBI-B review (publication one). For the same group, the STOE effect size of 0.71 would be the 9th largest increase reported on the subscale in the existing body of STEBI-B literature (publication one).

Based on the evidence provided in this dissertation, the claim could be made that participation in the SC308 course (refer to publication two for a full description) covaries with improved science teaching efficacy beliefs for preservice primary teachers. According to STEBI-B data presented in the third publication, the 67 remaining cohort members showed highly significant increases to their science teaching efficacy beliefs ($F(1,66)=60.24, p < 0.0001$). For the cohort, the subscale growth was more even in the SC308 course, with the PSTE and STOE subscales showing moderate Cohen’s $d$ effect size increases of 0.61 and 0.68 respectively. The trends remain evident in the STEBI-B data collected from the larger sample of 367 preservice teachers presented in the fourth publication, where a MANOVA again showed statistically significant STEB increases within iterations of the SC308 subject ($F(1,366)=248.78, p<0.0001$). The SC308 subscale growth trends are the reverse of those reported on the SC108 course. The mean STOE growth for the 367 SC308 participants was small-to-moderate (Cohen’s $d=0.38$) and similar to the mean delineated within the STEBI-B literature (Cohen’s $d=0.43$). The large PSTE growth
(Cohen’s d=0.86) was slightly higher than the STEBI-B literature mean (Cohen’s d=0.83) and ranks 25th overall (publication one).

The full science program (SC108 and SC308), if experienced in the intended degree sequence and course formats, appears to have a positive covariant relationship with the science teaching efficacy beliefs on preservice primary teachers. The cohort of preservice teachers, which was the focus of the research presented in the third publication, showed highly significant increases to their science teaching efficacy beliefs over the duration of the science program (F(1,60)=67.86, p<0.0001). Analyses of the subscales shows large PSTE growth (Cohen’s d=0.80) and very large, and quite unique, STOE growth (Cohen’s d=1.08). Evidence presented in the fourth publication suggests these overall STEB growth trends are consistent in a larger sample of 234 preservice teachers (F(3,699)=95.345, p<0.0001). For this group, PSTE and STOE effect sizes remained large but declined slightly from those presented in the deeper cohort investigation (publication three). The PSTE growth was large (Cohen’s d=0.74) but was still below the STEBI-B literature mean (see publication one). The STOE growth remained very large for the expanded sample (Cohen’s d=0.96), a growth rate which ranks fourth across 25 years of STEBI-B research.

Evidence collected and analysed in the action research project presented in the sixth publication allows for a tentative claim to be made that the desirable outcomes of the SC308 course can still be achieved with an online delivery mode, in place of the more traditional
face-to-face delivery mode. A reflective pre- and post-test administration of the STEBI-B was used to measure preservice teachers’ science teaching efficacy beliefs in the reflexive action research framework. A MANOVA indicated that respondents’ science teaching efficacy beliefs underwent highly significant change as they experienced the modified, online version of the SC308 subject (F(1,22)=42.44, p<0.0001). Their large PSTE (Cohen’s d=1.37) and STOE (Cohen’s d=0.99) would be the 9th and 4th largest pre- to post-test increases reported in the STEBI-B literature respectively. While such findings are undeniably promising, contextualisation within the existing body of literature should be treated with caution. Even though the findings are statistically valid and reliable, additional contextual issues mitigate their strength. Factors such as the smaller sample size, the reflective STEBI-B administration, potential response bias and the absence of any possible dissenting perspectives prevent definitive conclusions from being drawn. Nevertheless, such findings provide a compelling basis for continued research into the transition of science courses from face-to-face to online modes of delivery.

There is a plethora of qualitative data presented in the third and sixth publications that attest to the improvement of preservice primary teachers’ science teaching perceptions as they experienced the SC108 and SC308 courses. Harvard one-minute paper data, presented in the third publication, show tremendous simultaneous increases in positive responses and decreases in negative responses to the SC108 course during the semester. Such findings appear to be confirmed via cross triangulation with semi-structured interview data, wherein preservice
teachers expressed greater confidence in their ability to teach science. For example, Malcolm said “The big moment where I realised that I’d actually be confident teaching (science), was last night when I realised how much I’d done in this course (SC108)”. For the SC308 course, participants reported similar declines and increases in negative and positive reactions to the course respectively over time. Interviewees felt they had developed practical inquiry skills that would enable them to plan and teach quality science lessons. Daisy expressed such a perception, “The fact that I have completed a whole unit of work makes me realise that I can actually teach science”. The qualitative data presented in the sixth publication suggests similar positive science perceptions can develop in participants during a modified, online iteration of the SC308 course. Harvard data shows a similar disparity between positive (115 instances) and negative (21 instances) word choices at the midway point of the semester. Examples of anonymous student feedback at the end of the semester, such as ‘I actually feel equipped to have a go teaching science’ and ‘I have increased my confidence in teaching science’, highlight participants’ improved perceptions of science teaching.

**Question 3**

- How do the complex, innovative science courses appear to impact the long-term science teaching efficacy beliefs and reported science teaching practices of past preservice teachers who have transitioned to inservice status?

**Answer (Publications three and five).**
Prior to considering the transition of preservice teachers to inservice status, it is worth first assessing the durability of the aforementioned STEB increases for the final two years tertiary study which occurred after the completion of the science programs. The longitudinal 4-year cohort investigation (the subject of the third publication) affords such an opportunity to assess the durability of STEB growth, occurring during the science program, for the remainder of the participants’ degrees. For a year after the completion of the science program, the cohort’s STEBs did not show any significant changes (F(1,29)=1.98, p=0.167). Data collected in the cohort’s final year of study actually showed a statistically significant increase to their science teaching efficacy beliefs, despite not receiving any formal science education in this delay period (F(1.68,53.83)=8.165, p=0.001). While far from conclusive, such a finding may hint at the capacity of the science program to affect long-term growth for primary science teachers.

STEBI-A data collected from prior preservice teachers who had transitioned to inservice status was used to assess the long-term durability of the science teaching efficacy belief growth reported at the tertiary level. A total of 75 primary teaching graduates, who were teaching at the time of response, provided both STEBI-B data as preservice teachers at the completion of the science program and STEBI-A data after they had begun teaching professionally. In this instance, the unique complementary nature of the STEBI-A and STEBI-B instruments allowed for a direct, quantitative comparison of STEBs across the preservice to inservice teaching transition that is seldom presented in the literature (as discussed in publication one).
The graduate teachers’ STEBs had remained durable from their final undergraduate occasion of testing (the completion of the SC308 course). A MANOVA showed that there was no statistically significant STEB effect due to occasion of testing (F(1,74)=0.348, p=0.557). Of note was both the PSTE subscale increase (Cohen’s d= 0.39) and STOE subscale decrease (Cohen’s d= -0.27). In fact, analysis shows that this was the first time that there was no significant difference between the subscales (F(1,74)=0.264, p=0.609). Such emergent trends have implications to be unpacked in further discussion on page 360.

The participants who experienced the science program (SC108 and SC308) reported a high frequency of science teaching with active, student-centred pedagogies that directly contradict the common themes of avoidance (Angus, 2003; Tytler, Osborne, Williams, Tytler & Clark, 2008) and teacher-centred approaches (Hawkins, 1990; Kelly, 200; Yates & Goodrum, 1990) which commonly emerge in the science education research literature. Evidence presented in the third publication suggests the participants were willing to teach science, as around 75% taught science on an in-school practical experience placement, despite less than half actually witnessing science being taught within their placement schools. The findings presented in the fifth publication indicate that the participants’ reported willingness to teach science as preservice teachers seemed to extend to their early career teaching practice. Indeed all but one of the interviewees reported teaching science consistently in their school contexts, with the one exception filling a role where science teaching was not a part
of her designated curriculum. Themes such as “student centred learning”, “inquiry learning”, “hands-on learning” and “cross curricular integration” featured prominently in the interviewees’ descriptions of their science teaching practices. It appears that the graduates perceived their experiences in the science program (SC108 and SC308) to be instrumental to their science teaching practice, as 90% of relevant commentary suggested that their tertiary science experiences had a positive impact on their science teaching practices.

More promising still was the interviewees’ tendencies to assume roles “above and beyond” the base requirements of classroom teachers in science education. The graduates engaged in key science education roles such as representing schools at science professional development courses, developing resources for school science curricula, running an extra-curricular science club and volunteering as a school-wide science coordinator.

**Research limitations**

While the key questions guiding this extended research project have been answered, there are limitations that mitigate the conclusions which can be made from the research presented across the six publications. The following paragraphs will outline the major limitations of the research presented in this dissertation.

The absence of an experimental design has prevented causal relationships between the science program (SC108 and SC308) and increases to participants’ science teaching efficacy beliefs from being established. The quasi-experimental designs used throughout this dissertation present inherent
threats to the validity of findings, which the lead researcher has considered at length. This issue was also evident within the STEBI-A/B meta-analysis (publication one) as much of the existing science education research lacked the experimental design necessary to attribute causality. Such an issue is further escalated by the lack of immediate contextual knowledge available to the outsider; essentially diminishing understanding of how the education educational design, and other confounding variables, relate specifically to changes to participants’ science teaching efficacy beliefs. The problems caused by the absence of experimental design and the pitfalls of limited contextual clarity have been addressed in this doctoral dissertation via: expanded participant sampling from multiple cohorts to strengthen the argument for covariance, the publication of a comprehensive description of the science interventions (see publication two) and the use of mixed methods approaches to data collection.

As is often the case in the social sciences, participant sampling was an issue at times within the research presented in this doctoral dissertation. It should certainly be noted that appropriate sample sizes were achieved within this research; indeed, the sample achieved in the longitudinal STEBI-B research into multiple iterations of the science program (SC108 and SC308) was particularly robust. The surveying of participants on multiple occasions, both within and across publications, was at times marred by attrition and inconsistent response rates. Sampling from a population of graduate teachers (publication five) was a considerable challenge. The initial sampling phase of emailing graduates through the university alumni office yielded a response rate of 0.5%. A targeted social media campaign was used to increase the sample; this approach yielded a much stronger 31% response rate. This
second approach was crucial in the acquisition of a sample large enough to ensure statistical assumptions were met. Despite the acceptable sample size, approximately only one fifth of the preservice teachers who provided full undergraduate STEBI-B datasets were surveyed as inservice teachers. Even though the surveyed graduates showed demonstrably similar undergraduate STEB scores to their unsurveyed counterparts, the risk that this sample is not completely representative of the population cannot be dismissed.

There are additional smaller limitations that emerged within this research project. Issues such as survey fatigue and survey response bias cannot be disregarded when interpreting the research findings. Survey fatigue refers to the diminished thought and consideration participants may put into their responses when required to complete a survey on multiple occasions over a relatively short period of time (Bryman, 2016; Burns, 2000; Kervin, Wilma, Herrington & Okely, 2006). It is acknowledged that survey fatigue may have been an issue within the deep cohort investigation (publication three) as the STEBI-B was administered 26 times over the four-year period. This problem has been somewhat ameliorated by delayed testing periods (i.e. 6 months between STEBI-B administrations on some occasions) and cross triangulation with other sources of data, as evidenced by the variance and continued growth in the cohort’s STEB scores. The risks associated with survey fatigue were also reduced with the inclusion of a broader quantitative STEBI-B research project (publication four), wherein respondents provided data on only four occasions, to confirm findings presented in the cohort investigation (publication three). Survey response bias, also informed by social desirability bias, occurs when an individual alters his or her responses to reflect what he or she believes the researcher or wider community would
want, thus diminishing the validity of any conclusions which may be based on the data (Burns, 2000). Due to the opaque nature of intention within human interaction, it is highly likely that response bias was a confounding variable in the research presented across this doctoral dissertation, much like it would be across all forms of social science research. This fundamental limitation of educational research has been addressed broadly through cautious, indefinite presentation and discussion of findings. For the undergraduate research, the power imbalance between academics and students was addressed by using outside researchers, providing repeated statements of participant rights and ensuring participant anonymity from academics. While the same power issues were not evident in the graduate teacher research, individuals who would have perceived their views as dissenting may have elected to not participate in the research project. The following section will discuss directions for future research and implications for teaching practice that have arisen from the results presented within this doctoral dissertation.

**Important Discussion Points**

The contrast between the PSTE and STOE subscales was a major point of interest within this doctoral dissertation. The STEBI review (publication one) illustrated that in the overwhelming majority of applicable cases preservice teachers’ science teaching outcome expectancies were lower (King & Wiseman, 2001; Mashnad, 2008) and showed less growth (Fleming, 2007; Hudson, 2004) than their personal science teaching efficacy beliefs. STEBI researchers appear to have linked these issues with the construction of the instruments, with critiques of the reliability and validity of the STOE subscale (Cannon & Scharmann, 1996; Hechter, 2010; McDonough & Matkins, 2010). In this doctoral dissertation both the STEBI-A and STEBI-B
instruments have proven to produce reliable and valid PSTE and STOE measurements (publications three, four, five and six). The researcher believes this subscale disparity may be symptomatic of perplexing cynicism where more novice preservice teachers feel they can have a more significant impact of students’ science learning than science teaching more generally. The emergence of such cynicism would appear to be supported by reports of the poor personal science experiences of preservice teachers (Cobern & Loving, 2002; Jarrett, 1999; Mulholland & Wallace, 2001). Predictably, the same cynical STEBI subscale trends were evident within the inservice teacher STEBI-A research (Ewing-Taylor, 2012; Haney, Wang, Keil & Zoffel, 2007; Lakshmanan, Heath, Perlmutter & Elder, 2010). The preservice teachers sampled in this doctoral did not show the cynicism commonly seen in the STEBI-B literature as their STOE scores were consistently higher and frequently showed higher growth rates than their PSTEs. Simply put, the preservice teachers who experienced the science program (SC108 and SC308) seemed to hold an aspirational mindset as they did not yet believe they could fulfil their own expectations of science teaching to improve students’ science understandings. When surveyed again as inservice teachers, the graduates’ PSTE and STOE scores no longer displayed statistically significant differences, indicating they now perceived themselves as meeting their own standards for science teaching. The researcher hypothesises that consistently high science teaching outcome expectancies are pivotal for educators to engage in actions that will lead to consistent and sustained improvements to personal science teaching efficacy beliefs.

The teacher variable has seldom been an overt focus in research into the tertiary science education of preservice primary teachers (see publication
one). Given the importance of constructivism plays in learning processes (Vygotsky, 1977) and an academic’s central role as the facilitator of any tertiary science program, it is highly likely that the teacher variable can serve as a confound to establishing covariant links between science intervention and participant outcomes. In this doctoral dissertation, the STEBI-B data collected from multiple SC108 and SC308 offerings over an eight-year period (see publication four) afforded a unique opportunity to tentatively investigate the impact of the teacher variable. There were two instances where the co-creator of the science program, a highly experienced academic with over thirty years of combined secondary and tertiary science teaching experience, was unavailable to teach the SC308 course. In 2009, the co-creator was replaced by a pair of less experienced academics and in 2014 he was replaced by a pair of inexperienced doctoral students. Participants in both SC308 offerings showed significant PSTE increases, suggesting the educational design is robust enough to still influence student outcomes even with, at times, drastic changes to the compositions of teaching teams. Conversely, these two SC308 iterations were the only offerings where the participants’ STOE scores did not display statistically significant growth.

One interpretation could be that preservice teachers value experienced science teachers as models for the development of aspirational mindsets, as expressed by higher STOE scores. Unfortunately, the dire state of primary science education in Australia (Tytler, 2007) combined with increasing rates of casualization in the tertiary sector (Klopper & Power, 2014; Rothengatter & Hil, 2013) can make it more challenging for preservice teachers to interact directly with experienced ‘model’ science teachers in extended, meaningful ways. Aside from employing diverse and experienced teaching teams,
approaches such as in-subject practical science teaching experiences (Velthuis, Fisser & Pieters, 2014), teacher mentoring (Kenny, 2012), links to professional experience blocks (Flores, 2015) and formal partnerships between schools and universities (Lumpe, Czerniak, Haney & Beltyukova, 2012) could be used connect preservice teachers with consummate science teachers in order to affect sustained STOE growth.

The common use of pre- and post- test STEBI administrations combined with the varied, and often simultaneous use of different pedagogical approaches within the STEBI literature (publication one) make it challenging to determine how specific approaches to tertiary science education influence participants’ science teaching efficacy beliefs. Understanding the value of different innovative practices is often achieved through qualitative research, such as interviewing students and academics for their interpretations of the learning experiences (Palmer, 2008; Mulholland & Wallace, 2001). It is, however, acknowledged that qualitative approaches are appropriate as course designs, including SC108 and SC308, often link different approaches in inextricable ways. The weekly administration of the STEBI-B used for part of this doctoral dissertation (publication three) allowed for deeper insights into the impact of some different learning opportunities. During the cohort’s iteration of the SC108 course the transition from teacher-centred transmission to student-lead inquiry and group teaching served as the catalyst for steep, continuing increases to their science teaching efficacy beliefs. It could be inferred that the student centred approach was crucial to such an upswing, but attributing the growth to specific approaches was not possible. According to interview data (publications three and five) students’ responded favourably to different elements despite receiving similar educational experiences.
(cooperative learning, student-inquiry, alternative conception targeting, curriculum development, etc.). After completing the in-school practical science teaching experience offered in SC308 the cohort showed the largest single week increase to their personal science teaching efficacy beliefs (Cohen’s d=0.25). This fits with the existing literature where the value of practical science teaching experiences has long been established (Bautista, 2011; Lewthwaite, Murray & Hechter, 2012; Palmer, 2006; Velthuis, Fisser & Pieters, 2014). Interestingly, the benefits of firsthand science teaching experiences may be lost if such opportunities are not contextualised with a tertiary science course (Ebrahim, 2012).

The vast majority of STEBI research reports on face-to-face science interventions rather than online, distance based science interventions. It should be noted that online modes of delivery are more prominent in the STEBI-A literature (see publication one). Still, there are some examples of online teaching within the STEBI-B literature. Slater, Slater and Shaner (2008) used online learning modules to supplement a face-to-face science course where participants showed improved content knowledge and science teaching efficacy. Haeusler and Lozanovski (2010) compared on-campus and distance iterations of a cooperative science course focusing on curriculum development. The distance education cohort were provided with group wikis and forums to replace the face-to-face group meetings, which would be used in an on-campus course delivery. Both groups showed statistically significant STEB increases, with no reported differences between them. There is now some evidence indicating that the SC308 course, originally designed for face-to-face delivery, may be able to sustain its influence when delivered via a distance mode of education. Participant data within the action research
presented in the sixth publication shows that they perceived significant increases to their PSTE (Cohen’s d=1.367) and STOE (Cohen’s d=0.991) scores. While valid and promising, such results are far from definitive due to the modified reflective STEBI-B administration and the smaller number of respondents relative to earlier investigations into face-to-face deliveries of SC308 (publications two, three and four).

Qualitative data suggest the graduate teachers who completed the science program (SC108 and SC308) showed professional resilience as they overcame hindering factors to their science teaching practice from within their school contexts. Through interview data, inservice teachers (publication five) expressed beliefs that their school science cultures had mixed influences on their reported science teaching practices. Negative science culture themes such as “low science priority”, “science marginalisation”, “the crowded curriculum”, “other teachers”, “resources” and “science outsourcing” echo many of the issues established in broader national studies (Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007). However, rather than adopting common coping mechanisms of avoidance (Angus, 2003; Martin, Mullis, Foy & Hooper, 2016; Tytler et al., 2008) and teacher-centred approaches (Goodrum & Rennie, 2007; Hawkins, 1990; Kelly, 200; Yates & Goodrum, 1990), the interviewees often actively overcame perceived hindrances. They described: using cross curricular integration to overcome time restraints and the crowded curriculum, campaigning for funding and adapting pedagogies to address resource limitations and assuming voluntary science leadership positions to improve the status of science teaching within their schools. Although the evidence is not conclusive due to the qualitative method, limited sample and high change of response bias, it could be
hypothesized that these early career primary science teachers are not simply resilient to professional adversity; they could act as agents of change to affect long term changes to school science cultures.

**Directions for Future Research**

There are a number of worthwhile directions for future research that have emerged from the results presented within this doctoral dissertation. First, experimental research with control groups should be used to determine if the covariant relationship between the science program (SC108 and SC308) and preservice teachers’ improved STEBs is also causal. Furthermore, the need for increased proliferation of experimental research designs is clear within the STEBI literature (publication one) which still appears to rely heavily on quasi-experimental research. Second, direct research into the science teaching practices of the, now graduate, primary teachers is needed to potentially confirm and the tentative emergent trends of student-centred science teaching practice shown in the fifth publication. Indeed, in the current body of science education research there is a heavy reliance on self-reporting to gain insight into time spent teaching science and how science is taught (Angus, 2003; Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007; Gough et al., 1998; Jarvis & Pell, 2005). Firsthand research into primary science teaching practices should also expand to include broader school science cultures. Research into negative science attitudes (de Laat & Watters, 1995), science marginalisation (Appleton & Kindt, 2002) and student disengagement (Goodrum, Hackling & Rennie, 2001) allow inferences about school science cultures to be made, but next step is for science teaching cultures at the primary level to be the primary focus of future research. A fuller understanding of school science cultures could lead to the informed
development of science programs for both preservice and inservice teachers. Third, the teacher variable needs to become an overt area of focus in this field moving forward. Despite being central to all forms of education and a clear confounding variable in the establishment of links between interventions and STEBs, the teacher variable is seldom considered overtly in the STEBI literature (publication one). The research presented in this doctoral dissertation was able to investigate the teacher variable briefly, but this was not a central focus imbedded within the research design. There would be substantial value in educational designs that can lessen the impact of the teacher variable in terms of continuity and broader impacts. Fourth, globalisation and rapid technological advancement need to be addressed in the STEBI literature through investigation into how traditional face-to-face science interventions can be transitioned to online modes of delivery. This doctoral dissertation has presented some evidence that the face-to-face SC308 course can be transitioned to a distance mode of delivery, although this base evidence needs to be expanded upon to ensure equivalence. Fifth, the reported issues with sampling graduate teachers give rise to the need for meta-research in this area, as role of social media needs to be further elucidated in science education research.

**Implications for Science Teaching Practice**

Implications for science teaching practices can be taken from the findings presented across the six publications comprising this doctoral dissertation. The extensive meta-analysis of science interventions, pitched at preservice and inservice teachers, presented in the first publication is a clear and powerful testament to the capability of student-centred, inquiry-based pedagogies to affect STEB growth in educators at different career stages. The
The collective power of a the 25-year body of STEBI literature helps to build a compelling argument for science educators to move away from more traditional transmissive, content heavy educational designs. The firsthand research presented in this doctoral dissertation makes a meaningful contribution to the existing literature. The SC108 course, a cooperative, inquiry based course framed by participants’ alternative Astronomy conceptions, and the SC308 course, a deep project-based extension of the core inquiry skills acquired in SC108 via intense curriculum development and practical teaching experience, have both shown to covary with significant STEB growth in preservice primary teachers which remain durable as they transition into their teaching careers. Even though it is neither infallible nor a panacea for all of the issues permeating science education, the science program is now a proven and replicable way of educating preservice primary teachers to become confident and competent practitioners. The Interactive Educational Design Model (IEDM) could assist tertiary science educators to modify the science program to suit their different contexts. Evidence presented in the sixth publication suggests that the SC308 course can be modified to provide distance education students with opportunities to develop curriculum collaboratively. Distance students’ high levels of engagement and reported STEB growth lend credence to the use of online learning for equitable tertiary science education experiences. Regardless of the pedagogies of future science courses, action research needs to become a core aspect of future educational designs to ensure continued improvement of the quality of science education even as educational contexts continue to change. The following section provide a brief conclusion to this extended research project.
Conclusion

The cornerstone of a successful system of science education is a base of confident and competent teachers. According to the existing science education research literature, many Australian primary teachers feel neither confident nor competent in their ability to teaching science; which seems to lead to infrequent, teacher-centred science teaching practice. The findings presented within this doctoral dissertation show that the complex, innovative science program (SC108 and SC308) covaries with large science teaching efficacy belief increases in preservice primary teachers to an international standard; even with variations to contexts, teaching team composition and modes of delivery. Furthermore, the science program seemed to engender participants with a sense of professional science teaching resilience as they showed: durable STEBs as they transitioned to inservice teaching status, a willingness of overcome hindering factors within their school science cultures, a desire to commit to science education by undertaking roles ‘above and beyond’ the requirements of an early career classroom teacher, and most importantly, a capacity to teach science using varied, deep and student-centred pedagogical approaches. While there are still limitations and unanswered questions, the evidence presented builds a compelling argument that the science program may equip preservice primary teachers with the skills, knowledge and attitudes needed to act as agents of change in a science education system mired in cycles of negative attitudes and underwhelming achievement levels.
References


Appendix One: Ethics Documentation

Mr James Deehan  
School of Teacher Education

Dear James,

Thank you for the additional information forwarded in response to a request from the Faculty of Education Human Ethics Committee.

The Faculty of Education Human Ethics Committee has approved your proposal An exploration of the factors affecting primary teachers’ science teaching efficacy beliefs and science teaching practices as they transition from pre-service to in-service stages. for a twelve month period from 19 December 2015.

The protocol number issued with respect to this project is 303/2014/36. Please be sure to quote this number when responding to any request made by the Committee.

Please note the following conditions of approval:

- all Consent Forms and Information Sheets are to be printed on current CSU letterhead;
- you must notify the Committee immediately in writing should your research differ in any way from that proposed. Forms are available at http://www.csu.edu.au/research/ethics_safety/human/ehr_managing;
- you must notify the Committee immediately if any serious and or unexpected adverse events or outcomes occur associated with your research, that might affect the participants and therefore ethical acceptability of the project;
- amendments to the research design must be reviewed and approved by the Faculty Human Ethics Committee or, if no longer minimal risk research, referred to the University Human Research Ethics Committee. Forms are available at the website above;
- if an extension of the approval period is required, a request must be submitted to the Faculty Human Ethics Committee or if no longer minimal risk research referred to the University Human Research Ethics Committee. Forms are available at the website above;
- you are required to complete a Progress Report form, which can be downloaded from the link above, by date if your research has not been completed by that date;
- you are required to submit a final report, the form is available from the website above.

You are reminded that an approval letter from the FHEC constitutes ethical approval only.

Importantly, if your research is being conducted in public schools you will need to seek SERAP approval from the Department of Education & Communities https://www.det.nsw.edu.au/media/downloads/about-us/statistics-and.
If your research involves the use of radiation, biological materials or chemicals separate approval is required from the appropriate University Committee.

Please don’t hesitate to contact me if you have any inquiries about this matter.

Yours sincerely,

[Signature]

A/Professor Fran Press
telephone 02 6338 4287
e-mail FHEC_Education@csu.edu.au
Education Faculty Human Ethics Committee
24 March 2015

Mr James DEEHAN
School of Teacher Education

Dear James,

Thank you for providing further information in relation to your request for a variation for your research project *An exploration of the factors affecting primary teachers’ science teaching efficacy beliefs and science teaching practices as they transition from pre-service to in-service stages* protocol number 300/2014/36 and is pleased to approve the variation.

We have confirmed with the University Ombudsman and CSU Privacy Officer, Miriam Dayhow that due to National Privacy Principals Student Banner cannot be used for the recruitment of research participants. To do so would be using data for a purpose other than that for which it was given and this is in contravention of the Privacy and Personal Information Protection Act. If you would like to propose a new method of recruiting participants not previously approved, the committee will be happy to expedite the review of your application.

Please don’t hesitate to contact me if you have any enquiries about this matter.

Yours sincerely,

[Signature]

Dr Martin Hall
(Acting Presiding Officer)
telephone 02 6929 2740
e-mail FHEC_Education@csu.edu.au
Education Faculty Human Ethics Committee
April, 2011

Dear Student,

Associate Professor David McKinnon at Charles Sturt University is conducting an Action Research Project (ethics number - 2006/122) into the teaching of the Science and Technology curriculum subjects EMS108 and EMS308 during 2011.

The Action Research involves implementing a package of learning materials dealing with Problem Based Learning, Cooperative Learning and Astronomy in the context of science education in the semester during which these subjects are normally taught: Autumn Semester for EMS108 and Spring Semester for EMS308.

The study seeks to investigate, by questionnaire, observation and interview, the knowledge developed and the attitudes towards the teaching of science in Primary Schools involving the materials and approaches employed. Further, the study will also involve post-intervention questionnaires conducted during the last scheduled lecture hour for the subject.

It is hoped that the information gained from this study will improve the teaching of science and technology in primary schools and improve pre-service teachers’ knowledge and skills in the use of Information and Communications Technologies (ICTs) as a learning tool in the science classroom.

As students in EMS108, you have already completed the Astronomy Diagnostic Test (ADT), for your own benefit, to map your knowledge deficits in the Astronomy content of the Science and Technology K-6 Syllabus. At the end of the semester, you will be asked to complete this instrument again to demonstrate for yourself how much you have learned. In addition, we will ask you to complete a Subject Evaluation instrument, by paper and pencil response, and on that we will ask you to record your Student Number. The methodological reason for doing this is so that we can match your ADT results to your reactions to the subject as indicated by your responses on the Subject Evaluation.

To safeguard the responses that you make on the Subject Evaluation, one student nominated by you, and who is present at the final lecture, will be asked to collect the Subject Evaluations and to hold these in a place of safe keeping until after the final grades are submitted to the School of Teacher Education Assessment Committee. At that time, the Subject Evaluations will be released for analysis by the teaching team. You will NOT be required to do the Online Version but you can if you wish.

You should understand that we are interested in improving the offering of these subjects so that students may become better teachers of science and technology content when they undertake a Practicum and when they graduate. No student will be disadvantaged by offering honest feedback to the teaching team. To ensure that you do not feel any coercion to participate, the signed Consent Forms will be collected by a nominated student, placed in a sealed envelope, and only released to the teaching team by the student after the grades have been submitted to the Assessment Committee.

Should you decide that you do not wish your data to be included in this research study, you can indicate this fact on the Consent Form attached to this Information Form. A third party will extract your ADT responses both on the pre-and post-intervention occasions and also remove your completed Subject Evaluation before supplying the Action Researchers with the paper based data. These data will then be coded and entered into a Statistical Package where ALL identifying information will then be removed before any analysis is undertaken. Thus, your Subject Evaluation responses, though matched with your ADT responses, will not reveal who you are. We guarantee absolute anonymity of response in this regard.

If you have any queries about the process or consent forms, please do not hesitate to contact Associate Professor David McKinnon, on 02 63 384235 or e-mail dmckinnon@csu.edu.au.

Thank you for your ongoing support and engagement in the subject.
Yours sincerely,

A/Prof. David McKinnon
Chief Investigator
School of Teacher Education
Charles Sturt University
Bathurst. 2795
Ph: 02 6338 4235
e-mail: dmckinnon@csu.edu.au

For:
Executive Officer
Ethics in Human Research Committee
Charles Sturt University
Private Bag 99
BATHURST NSW 2795
Telephone 02 - 6338 4628
Appendix Two: Participant Information Sheet

PARTICIPANT INFORMATION SHEET

An exploration of the factors affecting primary teachers’ science teaching efficacy beliefs and science teaching practices as they transition from preservice to inservice stages

Chief Investigator
James Deehan
Bachelor of Education (Honours) (1st Class)
Completing a Doctorate of Education at Charles Sturt University, Bathurst Campus

Supervisor
Dr Lena Danaia
Primary Science Lecturer and Transition Coordinator
Faculty of Education
Charles Sturt University, Bathurst Campus

Co-Supervisor
Professor David McKinnon
Director (Academic)
School of Education
Edith Cowan University, Joondalup Campus

Invitation

You are invited to participate in a research study on the science-teaching efficacy and science teaching practices of graduate Australian primary teachers.

The study is being conducted by James Deehan, as part of his PhD research, within the Faculty of Education Charles Sturt University.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being conducted and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

1. What is the purpose of this study?
Previous research has shown that the performance of Australian primary students in science has declined. Primary teachers often lack confidence and competence in the teaching of science. This leads to the marginalisation and avoidance of science. This research aims to assess the science-teaching efficacy and science teaching attitudes of graduate primary teachers.

2. Why have I been invited to participate in this study?
We are seeking participants who undertook their tertiary science education at Charles Sturt University between from 2007 to 2014 (inclusive). Your name was selected from past graduates of CSU. We are also seeking graduate primary teachers from other tertiary institutions.

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3. What does this study involve?
If you agree to participate, you will be asked to complete two surveys and potentially participate in an interview. Details about the data collection methods are provided below:

- The Science Teaching Efficacy Belief Survey (Estimated Completion time of 5 minutes)
- The Science Attitudes and Science Teaching Survey (Estimated Completion time of 14 minutes)
- Interviews about your university experiences and science teaching – These interviews can be conducted via phone, email or in-person. The interviews will take approximately 15-20 minutes.

Your participation at all phases is optional. If you choose to complete the surveys, you are not obligated to participate in an interview.

4. Are there risks and benefits to me in taking part in this study?
There are no foreseeable risks associated with participating in this research project. This research will provide you with the opportunity to reflect on your science teaching. Your contribution will assist in the development of tertiary science programs that meet the needs of teaching professionals. Each time you provide data (maximum of three times – two surveys and/or an interview) you will go into a random draw to win a $200 Sanity giftcard, redeemable at any Sanity outlet Australia wide.

5. How is this study being paid for?
The research is being funded as a part of an Australian Postgraduate Award Scholarship.

6. Will taking part in this study (or travelling to) cost me anything, and will I be paid?
There are no financial costs associated with you participating in this study.

7. What if I don't want to take part in this study?
Participation in this research is entirely your choice. Only those people who give their informed consent will be included in the project. You will be in no way disadvantaged if you elect not to participate in the research project.

8. What if I participate and want to withdraw later?
You have the right to have your data removed at any time after you have participated in the research. To remove your data, send your request to the chief investigator (James Deehan) and it will all be removed from the research and permanently destroyed.

10. How will my confidentiality be protected?
Your name and institution will be replaced with code numbers and pseudonyms. Only the chief investigator (James Deehan) will be able to re-identify your information. The de-identified code numbers and pseudonyms
will be used to label data sets and for formal reporting. Data will be retained for at least 5 years at Charles Sturt University, Bathurst Campus.

Any information collected by the researcher which might identify you will be stored securely and only accessed by the researcher unless you consent otherwise, except as required by law. There are limits on assurances of confidentiality as law may subpoena research data/records.

11. What will happen to the information that I give you?
The data will be presented in peer reviewed journal articles that will contribute to James Deehan’s Doctoral Dissertation.

Your confidentiality will be fully maintained in all reporting of the data. Individual participants will not be identified in any reports arising from the project.

If you provide consent to have your interview recorded as an audio file, you have the right to review the file. Only the researcher will hear the audio recording. De-identified transcriptions of the interviews will be used for data reporting.

You have the right to view your raw data and/or have it explained to you by the chief investigator. You can also elect to receive any reports or publications within which the data are used.

12. What should I do if I want to discuss this study further before I decide?
If you would like further information please contact James Deehan. His contact details are listed below:

James Deehan Bachelor of Education (Primary) (Hons1)
PhD Candidate/ Research Assistant/ Sessional Staff Member
School of Teacher Education
Charles Sturt University
Panorama Avenue
Bathurst NSW 2795
Australia
Ph: +61 (02) 6338 4229
Mob: 0406 895 505
Email: jdeehan@csu.edu.au

13. ‘Who should I contact if I have concerns about the conduct of this study?’
NOTE: The Faculty of Education Human Research Ethics Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer.

Lisa McLean
Executive Officer
Faculty of Education Human Ethics Committee
Charles Sturt University
Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.

Thank you for considering this invitation.
This information sheet is for you to keep.
Appendix Three: Consent Form

CONSENT FORM

An exploration of the factors affecting primary teachers’ science teaching efficacy beliefs and science teaching practices as they transition from preservice to inservice stages

Chief Investigator
James Deehan
Bachelor of Education (Honours) (1st Class)
Completing a Doctorate of Education at Charles Sturt University, Bathurst Campus

Supervisor
Dr Lena Danaia
Primary Science Lecturer and Transition Coordinator
Faculty of Education
Charles Sturt University, Bathurst Campus

Co-Supervisor
Professor David McKinnon
Director (Academic)
School of Education
Edith Cowan University, Joondalup Campus

I agree to participate in the above research project and give my consent freely.

I understand that the project will be conducted as described in the Information Statement, a copy of which I have retained.

I understand I can withdraw from the project at any time and do not have to give any reason for withdrawing.

I consent to:

- completing a survey about my tertiary science education and science teaching efficacy
- completing a survey about my science teaching practice and science attitudes
- participating in an interview and having it recorded
- allowing the data that I provide to be used for formal research reporting and publications

I understand that my personal information will remain confidential to the researchers.

I have had the opportunity to have questions answered to my satisfaction.
NOTE: The Faculty of Education Human Research Ethics Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer.

Lisa McLean
Executive Officer
Faculty of Education Human Ethics Committee
Charles Sturt University
FHEC_Education@csu.edu.au
02 6338 4966

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.
**Appendix Four: The Science Teaching Efficacy Belief Instrument B (STEBI-B)**

First Name: ___________________________  
Surname: ______________________________

Date: _____/_____/_____

Please indicate the degree to which you agree or disagree with each of the following 30 statements below by circling the appropriate number to the right of each statement.

<table>
<thead>
<tr>
<th>Read each statement carefully before responding.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 When a primary school pupil does better than usual in science, it is often because the primary teacher exerted a little extra effort.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 I will continually find better ways to teach primary school science.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Even if I try very hard, I will not teach primary school science as well as I will most other KLAs.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 When the science grades of primary school pupils improve, it is often due to their teacher having found a more effective teaching approach.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 I know the steps necessary to teach primary school science concepts effectively.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 I will not be very effective in monitoring science experiments in the primary school.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 If primary school pupils are underachieving in science, it is most likely due to ineffective science teaching.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 I will generally teach primary school science ineffectively.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 The inadequacy of a primary school pupil’s science background can be overcome by good teaching.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 The low science achievement of some primary school pupils cannot generally be blamed on their teachers.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 When a low achieving primary school pupil progresses in science, it is usually due to extra attention given by the teacher.</td>
<td>5 4 3 2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I understand science concepts well enough to be effective in teaching primary school science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>13</td>
<td>Increased effort in science teaching produces little change in some primary school pupils’ science achievement.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Read each statement carefully before responding.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Uncertain</td>
<td>Disagree</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>-------</td>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td>14</td>
<td>The teacher is generally responsible for the achievement of primary school pupils in science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Primary school pupils’ achievement in science is directly related to their teacher’s effectiveness in science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>If parents comment that their child is showing more interest in science at primary school, it is probably due to the performance of their child’s teacher.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>I will find it difficult to explain to primary school pupils why science experiments work.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>I will typically be able to answer primary school pupils’ science questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>I wonder if I will have the necessary skills to teach science in primary school.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>Given a choice, I will not invite the principal to evaluate my science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>When a primary school pupil has difficulty understanding a science concept, I will usually be at a loss as to how to help the pupil understand it better.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>22</td>
<td>When teaching primary school science, I will usually welcome pupils’ questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>I do not know what to do to turn primary school pupils on to science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>I do not feel I have the necessary skills to teach science in primary school.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>After I have taught a science concept once, I will feel more confident teaching it again.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>26</td>
<td>I find science a difficult topic to teach.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>27</td>
<td>I understand science concepts well enough to teach primary school science effectively.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>I know how to make primary school pupils interested in science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>29</td>
<td>I feel anxious when teaching science content in primary school that I have not taught before.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>I wish I had a better understanding of the science concepts I will teach.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
The Personal Science Teaching Efficacy (PSTE) subscale Items

- Even if I try hard, I will not teach primary school science as well as most other Key Learning Areas.
- I will find it difficult to explain to primary school pupils why science experiments work.
- I wonder if I will have the necessary skills to teach science in primary school.
- Given a choice, I will not invite the principal to evaluate my science teaching.
- When a primary school pupil has difficulty understanding a science concept, I will usually be at a loss as to how to help the pupil understand it better.
- I do not know what to do to turn primary school pupils on to science.
- I do not feel I have the necessary skills to teach science in primary school.
- I find science a difficult topic to teach.

The Science Teaching Outcome Expectancy (STOE) Subscale Items

- When a student does better than usual in science, it is often because the teacher exerted a little extra effort.
- When the science achievement of students improves, it is most often due to their teacher having found a more effective teaching approach.
- If students are underachieving in science, it is most likely due to ineffective science teaching.
• The inadequacy of a student’s science background can be overcome by good teaching.

• When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.

• The teacher is generally responsible for the achievement of students in science.

• Student’s achievement is directly related to their teacher’s effectiveness in science teaching.

• If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child’s teacher.
Appendix Five: The Science Teaching Efficacy Belief Instrument A (STEBI-A)

First Name: ___________________________
Surname: ______________________________
Date: _____/_____/_____

Please indicate the degree to which you agree or disagree with each of the following 30 statements below by circling the appropriate number to the right of each statement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. I am continually finding better ways to teach science to my students</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. Even when I try hard, I don’t teach science as well as I do the other Key Learning Areas in the primary curriculum</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4. When the science achievement of students improves, it is most often due to their teacher having found a more effective teaching approach.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. I know the steps necessary to teach science concepts effectively.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6. I am not effective in monitoring science experiments.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7. If students are underachieving in science, it is most likely due to ineffective science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8. I generally teach science effectively</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>9. The inadequacy of a student’s science background can be overcome by good teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10. The low science achievement of some students cannot generally be blamed on their teachers.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11. When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
12. I understand science concepts well enough to be effective in teaching the primary science curriculum.  

13. Increased effort in science teaching produces little change in some students' science achievement.

<table>
<thead>
<tr>
<th>Read each statement carefully before responding.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Uncertain</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. The teacher is generally responsible for the achievement of students in science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>16. I find it difficult to explain to students why science experiments work.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>17. I am typically able to answer students' science questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
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<tr>
<td>18. I wonder if I have the necessary skills to teach primary school science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
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<tr>
<td>19. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>20. Effectiveness in science teaching has little influence on the achievement of students with low motivation.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>21. Given a choice, I would not invite the principal to evaluate my science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>22. When a student has difficulty understanding a science concept, I am usually at a loss as how to help the students understand it better.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>23. When teaching primary school science, I usually welcome student questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>24. I don't know what to do to turn students on to science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>25. Even teachers with good science teaching abilities cannot help some kids learn science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
The Personal Science Teaching Efficacy (PSTE) subscale Items

- Even when I try hard, I don’t teach science as well as other Key Learning Areas in the primary curriculum.
- I know the steps necessary to teach science concepts effectively.*
- I generally teach science effectively.*
- I find it difficult to explain to students why science experiments work.
- I wonder if I have the necessary skills to teach primary science.
- Given a choice, I would not invite the principal to evaluate my science teaching.
- When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.
- I don’t know what to do to turn students on to science.

*Denotes replacement items used to overcome incomplete data sets. The PSTE subscale remained reliable with the replacement items (Cronbach’s $\alpha = 0.812$).

The Science Teaching Outcome Expectancy (STOE) Subscale Items

- When a student does better than usual in science, it is often because the teacher exerted a little extra effort.
- When the science achievement of students improves, it is most often due to their teacher having found a more effective teaching approach.
- If students are underachieving in science, it is most likely due to ineffective science teaching.
• The inadequacy of a student’s science background can be overcome by good teaching.

• When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.

• The teacher is generally responsible for the achievement of students in science.

• Student’s achievement is directly related to their teacher’s effectiveness in science teaching.

• If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child’s teacher.
Appendix Six: Interview Questions

Opening Statement:
“Hello. Thank you for agreeing to participate in this research project. Before we begin, I’d like to ask if you have had a chance to review the information sheet and sign the consent form. Are you fully aware of your rights as a participant in this research project? Are there any questions you would like to ask before we begin? Remember that you have the right to end your participation in the research project and have your data removed at any time.”

Question 1
“What is your name? Remember that your anonymity is ensured in all data reporting. Only the interviewer will know your identity.”

Question 2
“At what institution did you obtain your teaching qualification? What years did you attend?”

Question 3
“What have your teaching experiences been since you have graduated? All institutions mentioned will be replaced by pseudonyms in the final transcript. Confidentiality is assured.”

Question 4
“How would you describe your science teaching practice? Do you feel confident to teach science? What science do you teach in your classroom? How do you teach it?”

Question 5
“Can you describe the formal science teaching you have received as part of your undergraduate teacher training? What years(s) did you receive this science education? In what ways do you believe that your tertiary science training has influenced your science teaching practice as a graduate primary teacher?”

Question 6
“What support have you sought or been offered to assist in your science teaching? Where does this support come from? How do your colleagues address science? Is science a priority in your school?”

Question 7
“Thank you for participating in this interview. Is there any final statement that you’d like to make in relation to this interview and/or your participation in this research project? You have the right to review the recording of this interview. You can have your data removed from the project at any time.”
Appendix Seven: Publication Two Submission Proof

Dear [Name],

Please find attached a submission entitled “The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model for the journal Studies in Science Education,” which is available to [you] at [this link].

The article comprises:
- Three brief biographies of [name], [name], and [name];
- An abstract of 150 words;
- The body of 3,000 words;
- One figure in black and white on pp. 33-35;
- Three tables, two of which are in landscape, on pp. 33-35 at the end of the manuscript.

If the article is accepted for publication, I can supply a high-quality TIFF of the Figure. I can also supply a high-quality color TIFF for the online version.

The keywords are: primary preservice teacher science education, teacher education, teacher learning, college science teaching, pedagogical content knowledge, educational design model, science teaching efficacy research.

The article is not under any consideration by any other journal.

My co-authors and I understand that at this time of the year there may be other events in the lives of both you and your referees, which may delay things a little.

We extend to you a very merry Christmas and happy New Year.

Kind regards,

David

David McKinnon

PhD

Director of [Institutional Title]

Professor of [Field]

---

Jim Ryder <j.ryder@education.leeds.ac.uk>

Thu, 12/23/2016, 4:56 AM

To: [David McKinnon] <d.mckinnon@ecu.edu.au>
Cc: [Other Recipients]

Dear David,

Thank you for the contact. I acknowledge receipt of the manuscript and will be in touch again shortly.

With best wishes,

Jim
Appendix Eight: Publication Three Submission Proof

Submission Confirmation

Thank you for your submission

Submitted to
International Journal of Science Education

Manuscript ID
TSED-2016-0531-A

Title
A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice elementary teachers

Authors
Deehan, James
Danaia, Lena
McKinnon, David

Date Submitted
20-Oct-2016
Submission Confirmation

Thank you for your submission

Submitted to: Journal of Research Science in Teaching

Manuscript ID: JRST-2016-11-0401

Title: A longitudinal investigation of the science teaching efficacy beliefs of multiple cohorts of preservice elementary teachers

Authors: Deethan, James
         McKinnon, David
         Danaia, Lena

Date Submitted: 13-Dec-2016
## Appendix Ten: Publication Five Submission Proof

### Research in Science Education

From students to teachers: Investigating the science teaching efficacy beliefs and experiences of a group of elementary teachers who have recently graduated from university  

--Manuscript Draft--

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<td>Keywords:</td>
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| Corresponding Author: | James Deehan  
                       | Charles Sturt University  
                       | Bathurst, NSW AUSTRALIA |
| Corresponding Author Secondary Information: | |
| Corresponding Author’s Institution: | Charles Sturt University |
| First Author:      | James Deehan |
| First Author Secondary Information: | |
| Order of Authors:  | James Deehan  
                       | Lena Darakia  
                       | David H McKinnon |
| Order of Authors Secondary Information: | |
| Funding Information: | |
| Abstract:          | The science achievement of elementary students, both in Australia and abroad, has been the subject of intensive research in recent decades. Consequently, much research has been conducted to investigate elementary science education. Within this literature there is a striking juxtaposition between tertiary science teaching preparation programs and the experiences and outcomes of both teachers and students alike. While many tertiary science teaching programs covary with positive outcomes for pre-service teachers, reports of science at the elementary school level continue to be problematic. This paper begins to explore this apparent contradiction by investigating the science teaching efficacy beliefs and experiences of a cohort of early career elementary teachers who had recently transitioned from pre-service to in-service status. An opportunity sample of 82 elementary teachers responded to the science teaching efficacy belief instrument A (STEB-A) and 10 graduates/early career teachers provided semi-structured interview data. The results showed that participants’ prior science teaching efficacy belief growth, which occurred during their tertiary science education, had remained durable after they had completed their teaching degrees and began their careers. Qualitative data showed that their undergraduate science education had had a positive influence on their science teaching experiences. The participants’ school science culture, however, had mixed influences on their science teaching. The findings presented within this paper have implications for the direction of research in elementary science education, the design and assessment of pre-service elementary science curriculum subjects and the role of school contexts in the development of early career elementary science teachers. |
Appendix Eleven: Important Constructs in Science Education Research

Important Constructs in Science Education Research

There are several constructs that need to be defined prior to conducting research into science education. The purpose of this section is to describe both the unmeasured and measured constructs. Regardless of whether constructs are explicitly measured within the proposed research, the reader requires a sound knowledge of all of these relevant constructs in order to gain a deep understanding of both the direction of the literature and this research project. The unmeasured constructs will be explained and discussed in relation to the research. While these constructs are not measured as dependent variables, the researcher recognises their importance as extraneous variables when outlining the research. This leads into an argument for the inclusion of the measured efficacy construct rather than the unmeasured constructs is presented.

Unmeasured Constructs

The purpose of this subsection is to explain and discuss the important, extraneous constructs that are not explicitly measured within the proposed research. The following section will describe the interrelated constructs of Pedagogical Content Knowledge (PCK), Content Representations (CoRes) and Professional and Pedagogical Experience Repertoires (PaPERs).

Pedagogical Content Knowledge and related constructs.

Pedagogical Content Knowledge (PCK) can be defined loosely as the synthesis of core content knowledge in a specified area of study and the pedagogies needed to deliver this information to an intended audience (Gess-Newsome, 1999; Hill, Ball & Schilling, 2008; Loughran, Mulhall & Berry,
Hill and others (2008) recognise that the prior knowledge and learning capacities of students directly affect both the content and pedagogical choices made by a teacher. In essence, by reacting to the learning needs of students with their own PCK, teachers are engaging in a complex, multi-tiered thought process to determine appropriate learning pathways. While many would posit that, a high level of PCK would be developed through experience or exist as a teacher’s innate ability, a growing body of research indicates that it can be developed through teacher education interventions (Franke, Carpenter & Levi, 2001; Saxe, Gearhardt & Nasir, 2001). Unfortunately, the construct of PCK is ill-defined and difficult to operationalise into teacher education practice. This is particularly problematic in the domain of science education as teachers struggle to find concrete teaching examples to develop their understanding of PCK (Van Driel, Verloop & De Vos, 1998). Loughran and others (2001) recognised this need for PCK explication and responded with the further development of Content Representations (CoRes) (Nillson & Loughran, 2011) and Pedagogical and Professional Experience Repertoires (PaPeRs) (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). Content Representations are the manifestations of the choices teachers make based on their PCK (Loughran, Mulhall & Berry, 2001). These are often concrete representations of abstract concepts that allow students to actively construct new knowledge. Pedagogical and Professional Experience Repertoires are developed as CoRes that are constructed through PCK are tested within a classroom and actively reflected upon (Abell, 2008). Loughran and others (2004) actioned PaPeRs as a series of reflective questions based on the concepts underpinning PCK. Such questions allow for the intrinsic elements
of PCK to be made explicit, thus allowing the teacher to identify their own strengths and weaknesses.

**Efficacy: The Measured Construct**

Efficacy is the construct that will be measured, given the complexity associated with the measurement of the aforementioned constructs of PCK, CoRes and PaPERs. A variety of research will be used to describe and explain the construct of efficacy. First, the essential research into educational efficacy will be provided. Second, with the nature of educational efficacy established, an argument for the measurement of efficacy in within the proposed research will be presented. This argument will be supplemented by outlining the positive effects that high teaching efficacy has teaching practice. Finally, the research into the science teaching efficacy will be presented.

**Efficacy in education.**

Aronson and others (1978) indicated that there is a direct link between students’ feelings and attitudes and their success in learning attempts. This links closely to the fundamental goals of education and provides potential for overcoming the previously discussed problems with construct definition. Self-Efficacy has a strong history within educational research literature. On an individual level it can be defined as a person’s internal evaluation of their ability to execute a particular task (Bandura, 1986; Tschannen-Moran & Woolfolk Hoy, 2001). It must be recognised that an individual cannot be extrapolated from context (Johns, 2006). Eccles and Wigfield (1995) consider this with the concept of task value, which is described as an individual’s belief that a task can achieve the intended purpose. Without a reasonable level of
personal efficacy and task value, it is unlikely that an individual will successfully complete a task to an acceptable standard.

Teacher efficacy is the confidence an individual has in themselves or their profession to help students to achieve pre-determined educational outcomes (Berman, McLaughlin, Bass, Pauly & Zellman, 1977). The construct is differentiated between Personal Teaching Efficacy (PTE) and General Teaching Efficacy (GTE). PTE describes an individual’s belief in their own ability to overcome contextually specific factors to promote student learning (Coladarci, 1992; Gordon & Debus, 2002). GTE is the belief that teaching in general can overcome external factors, such as socio-economic status, various learning needs and detrimental social experiences, to guide students towards achieving pre-determined goals (Tshannen-Moran & Hoy, 2001). The following subsection will present an argument for the focus on efficacy within the proposed research.

The argument for a focus on efficacy.

The previous sections have established the dire state of primary science education in Australia. Primary students, teachers and tertiary institutions all have different roles in addressing these problems in science education. This means that determining the success of any interventions is a complex endeavour. On a basic level, measuring the science achievement of primary students provides the most direct link to the goal of developing scientifically literate citizens (Bybee, 1997; Collins, 1997; Goodrum, Hackling & Rennie, 2001; Goodrum & Rennie, 2007; Lumpe, Czerniak, Haney & Beltyukova, 2012). However, as science is seldom taught in Australian primary schools (Angus, 2003; Goodrum, Hackling & Rennie, 2001; Rennie & Hackling,
much needs to change prior to measuring the science achievement levels of primary students.

*The relationship between efficacy and teaching practice.*

Teacher Efficacy has been found to correlate positively with desirable outcomes in both teachers and students (Goddard, Hoy & Hoy, 2000; Tschannen-Moran, Woolfolk-Hoy & Hoy, 1998). Early research into teacher self-efficacy found that teachers with high self-efficacy are more likely to continue utilising new programs and resources after the external support has been removed (Berman, McLaughlin, Bass, Pauly & Zellman, 1977). A covariant relationship has been established between high reported teaching efficacy and improved reading scores within minority students (Armor et al., 1976). Student achievement is also influenced more broadly by the collective teaching efficacy within a school environment. The students of teachers who reported high collective efficacy in their schools showed increased mathematical achievement levels (Goddard, Hoy & Hoy, 2000). In a more contemporary review of literature, Tschannen-Moran and others (1998) found that teachers with high efficacy scores were more likely to; spend time on academic activities, provide more help for students, encourage student-centred learning, try new teaching innovations and remain committed to the teaching profession. The work of Bandura (1977) validates the use of the self-efficacy construct within the proposed research. Bandura (1997) states that teacher self-efficacy can be improved with successful performance, vicarious experience, verbal persuasion and emotional arousal. All of these methods for improving self-efficacy can be delivered by tertiary science programs, thus potentially allowing for the positive effects of increased teacher self-efficacy to be experienced by preservice teachers as they enter their chosen field. The
following section will explore how efficacy is represented in science education research.

Efficacy in Science Education Research

A significant portion of the existing preservice science education literature is purely qualitative and cannot be generalised to alternate contexts (Appleton & Kindt, 2002; Skamp & Mueller, 2001; Ramey-Gassert, Shroyer & Staver, 1996; Tosun, 2000). This can be partially attributed to the difficulty in developing accurate, comparable measures for the intangible measures associated with science education. Learning and motivation are difficult constructs to define due to the intangible nature of the constructs. Even widely recognised and highly lauded IQ tests are not infallible as they can only measure intelligent actions rather than intelligence itself (Burton, Weston & Kowalski, 2009). Such unavoidable difficulty in construct measurement is likely to be a contributing factor to the possible emergence of a trend of overreliance on qualitative methodologies within both science education research and educational research as a whole. However, Riggs and Enochs (1990; 1991) developed two reliable and valid instruments for measuring the science teaching efficacy of teachers. The following section will describe both the STEBI-A and STEBI-B instruments because both are employed within the proposed research design.

The Science Teaching Efficacy Belief Instruments

Riggs and Enochs (1990) designed two science teaching efficacy instruments that were modelled on the Teacher Self Efficacy Scales (TSES) produced by Gibson and Dembo (1984). The Science Teaching Efficacy Belief Instrument A (STEBI-A) was designed to measure the science teaching efficacy of
The Science Teaching Efficacy Belief Instrument B (STEBI-B) was designed to measure the science teaching efficacy of preservice primary teachers (Riggs & Enochs, 1990). These instruments are equivalent as the STEBI-B was designed by modifying the items from the original STEBI-A to reflect the perspectives of preservice teachers.

The instruments require respondents to rate their level of agreement with statements on a 5 point Likert scale (Burns, 2000), ranging from ‘strongly disagree’ to ‘strongly agree’. The statements produce measurements of two subscales. The Science Teaching Outcome Expectancy (STOE) belief scale measures the participants’ broad views of science teaching related to why pupils perform as they do. The Personal Science Teaching Efficacy (PSTE) scale measures the participants’ beliefs about their own ability to teach science effectively. The items produce ordinal data as there are no observable or standardised intervals between the Likert responses (Kervin, Wilma, Herrington & Okely, 2006).

When the STEBI instruments were developed by Riggs and Enochs in 1990 but the PSTE and STOE subscales were shown to be reliable. For the STEBI-B the PSTE and STOE subscales were found to have Cronbach Alpha reliability coefficients of 0.90 and 0.76 respectively (Enochs & Riggs, 1990). Similar PSTE (Cronbach’s α=0.92) and STOE (Cronbach’s α=0.92) reliabilities were reported on the STEBI-A (Riggs & Enochs, 1990). Since the original publication of the STEBI instruments, the subscales have shown to be reliable across different contexts (Bleicher, 2004; Cartwright & Atwood, 2014; Czerniak & Lumpe, 1996; Finson, Beaver & Hall, 1992). Over the
years, the STOE subscale has shown to be inconsistent in its reliability (Lockman, 2006; Yang, Noh, Scharmann & Kang, 2014) which has often lead to its removal from research projects (Batiza et al., 2013; Velthuis, 2014).
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Velthuis, C. (2014). *Collaborative curriculum design to increase science teaching self-efficacy* (Doctoral dissertation, University of Twente, Enschede).