

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 (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. 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; Ramey-Gassert 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. Çakiroglu 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.

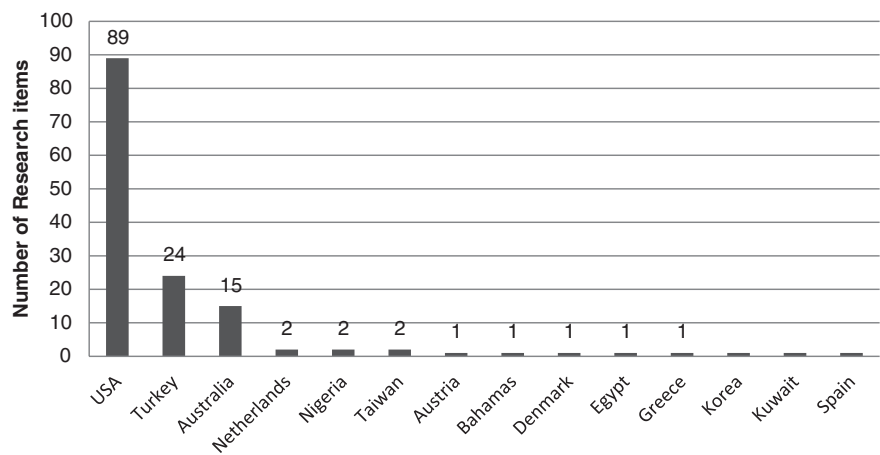


Fig. 1.1 Summary of the STEBI-B use of different nations

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'.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics*, 90(8), 694–706.

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 data bases, Primo provides access to journal articles, newspaper articles, books, Ebooks and other forms of research output. The following search terms were employed:

‘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, Informit, 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 articles 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 removed.

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 1.1 Research methods codes

Code	Research type	Number of STEBI-B uses	Description
4	Experimental design	>2	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 is 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
3	Longitudinal quasi experimental pre/post design	>2	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
2.5	Quasi Experimental pre/post—with multiple cohorts	>2	Research where multiple cohorts of participants responded to pre- and post-test versions of the STEBI-B, as they undertook a specified intervention
2	Quasi Experimental pre/post	2	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
1.5	Equivalent groups	2	Research where pre- and post-intervention STEBI-B data were collected from separate groups and compared as equivalent data (Suter 2006)

(continued)

Table 1.1 (continued)

Code	Research type	Number of STEBI-B uses	Description
1	Cross sectional	1	Research where the STEBI-B was administered to a group of pre-service teachers on one occasion to make comparisons with other variables
0	Qualitative/alternate research purpose	Variable	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)

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 1.2 Overview of innovative practices used within the analyses

Innovative practice	Description
Constructivism	Learning that occurs when an individual constructs their knowledge through active participation (i.e. discussion) within a phenomenon or situation (Slavin 1991; Vygotsky 1977)
Problem-based learning	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)
Integration with other key learning areas (KLAs)	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
Mentoring	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
Curriculum development	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
Inquiry learning	Inquiry learning allows participants to develop transferable 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
In-subject practical experience	This occurs when the intervention is designed with imbedded opportunities to teach science to students of the intended year levels
Links to practical experience blocks	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

(continued)

Table 1.2 (continued)

Innovative practice	Description
Cooperative learning	Cooperative Learning occurs when students work together in separate, complementary roles to complete a task that would otherwise be impossible to complete individually
ICT instruction/incorporation	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
Student centred investigation	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
Authentic tasks	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
Nature of Science	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
Misconceptions	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

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.

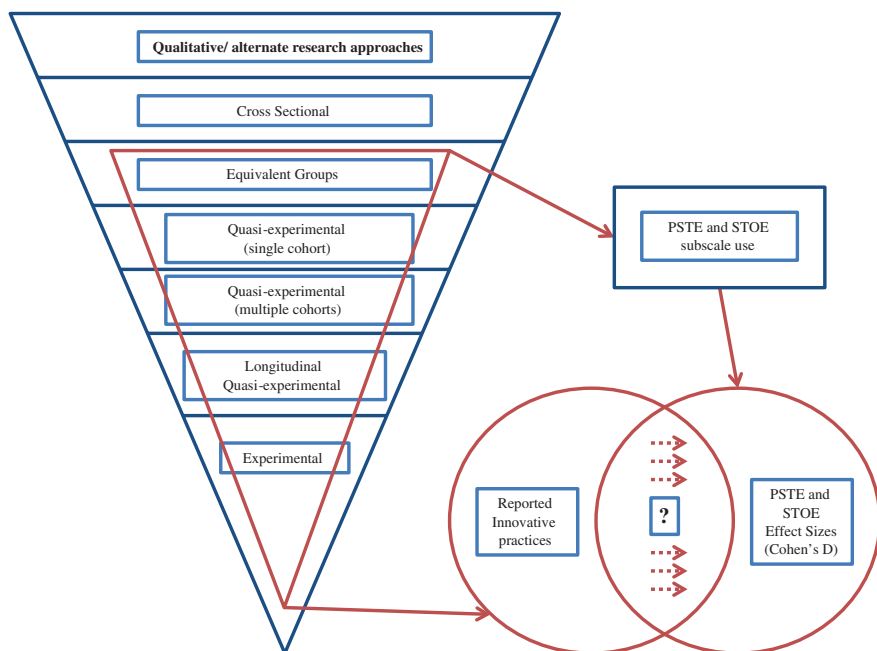


Fig. 1.2 STEBI-B review framework

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

STEBI-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 STEBI-B in a qualitative context (Lewthwaite et al. 2012; Tosun 2000; Watters 2007), thus limiting the relevance in this review. Tosun (2000) used the STEBI-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 STEBI-B to aid the personal science teaching reflection of a single pre-service teacher. The presentation of STEBI-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 STEBI-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 STEBI-B literature has been the modification of the STEBI-B instrument for more specific, alternative contexts. Such modifications of the original STEBI-B instrument fundamentally change the targeted constructs, thus the studies have been coded as ‘alternate approaches’. Wilson (2012) modified the STEBI-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 STEBI-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 STEBI-B modifications 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 STEBI-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 STEBI-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; Yilmaz-Tuzun and Topcu 2008) and science content knowledge (Mashnad 2008; Sarikaya 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. Yilmaz-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. Sarikaya 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 Paznokas 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 Paznokas 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 (Arigbabu and Oludipe 2010; Çakiroglu 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 (Bahcivan and Kapucu 2014; Kahraman et al. 2014; Olgan et al. 2014; Serin and Bayraktar 2014). Bahcivan 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 subscale 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 (Aydin and Boz 2010; Bayraktar 2011; King and Wiseman 2001;

Luera and Otto 2005; Velthuis 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; Velthuis 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, Velthuis 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 covaried 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-service teachers (Bursal 2008; Hudson 2004; Plourde 2002; Watters and Ginns 1999; Yilmaz 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 attributed these declines to contextual in-school factors, such as; insufficient time, limited 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 (Yilmaz and Cavas 2008). The STEBs 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 published 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 experiences (Cartwright and Atwood 2014; Flores 2015). Bautista and Boone (2015) found that participation in a mixed reality learning environment covaried with significant increases in the PSTE and STOE scores of 62 pre-service teachers. 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. Scharmann and Orth 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. McDonnough 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. Kahraman 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; Saçkes 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. Bayraktar 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 %)

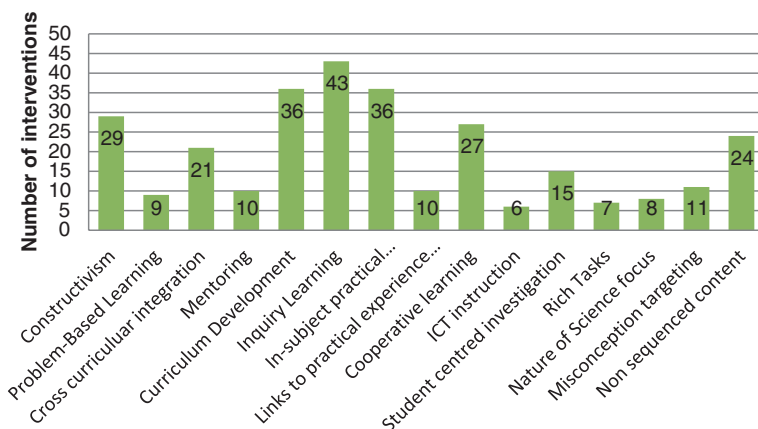


Fig. 1.3 Innovative practices included within the STEBI-B literature

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.

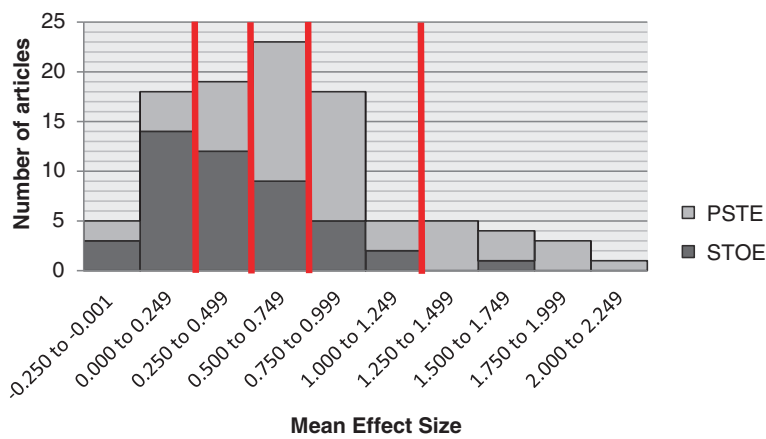


Fig. 1.4 PSTE and STOE distribution histogram

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 effects 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 1.3 Descriptive statistics for PSTE and STOE effect sizes

	Mean	Std. Deviation	N
MeanPSTE	0.833	0.512	55
MeanSTOE	0.429	0.357	46

Table 1.4 Correlation analysis for PSTE and STOE effect sizes

		MeanPSTE	MeanSTOE
MeanPSTE	Pearson correlation	1	0.628**
	Sig. (2-tailed)		0.000
	N	55	46
MeanSTOE	Pearson correlation	0.628**	1
	Sig. (2-tailed)	0.000	
	N	46	46

**Correlation is significant at the 0.01 level (2-tailed)

Table 1.5 Top 10 PSTE effect sizes

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

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 covary 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 STOE. 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 (Ozdelik and Bulunuz 2009; Palmer 2006a). Ozdelik 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 STOE of pre-service elementary teachers (Cross 2010; Deehan 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

Year	Author(s)	Innovative practices	Effect size
2002	Jabot	Curriculum development, links to professional experience blocks and alternative conception targeting	1.54
2015	Cooper	Mentoring, curriculum development, in-subject practical experience	1.13
2009	Ozdelik and Bulunuz	Inquiry learning, cooperative learning	1.11
2006a, b	Palmer	Cooperative learning, student-centred investigation	0.92
2011	Bautista	Integration with other KLAs, inquiry learning, in-subject practical experience, link to professional experience blocks, nature of science focus, alternative conception targeting	0.85
2010	Cross	Constructivism, mentoring, curriculum development, inquiry learning, in-subject practical experience, cooperative learning, student-centred investigation, alternative conception targetting	0.81
2009	Bleicher	Constructivism, curriculum development, cooperative learning	0.75
1999	Wingfield and Ramsey	Mentoring, curriculum development, in-subject practical experience, cooperative learning	0.71
2013	Deehan	Constructivism, problem-based learning, Integration with other KLAs, curriculum development, inquiry learning, in-subject practical experience, cooperative learning, ICT instruction. student-centred investigation, Rich Tasks	0.70
2015	Knaggs and Sondergeld	Curriculum development, inquiry learning, in-subject practical experience, student-centred investigation, nature of science instruction	0.69

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 Bayraktar 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. Ginns 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 STEBs. 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 on occasion, the mean STOE score was higher than the mean PSTE score only five times (e.g. Bayraktar 2011; Cross 2010; Deehan 2013). There is a similar disparity in the effect size changes reported on the STEBI-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; McDonnough 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; Enochs 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 STOE subscales needs 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 STOE subscale are compelling, addressing these issues would advance the body of research into valuable new directions.

References

- Andersen, A. M., Dragsted, S., Evans, R. H., & Sørensen, H. (2004). The relationship between changes in teachers' self-efficacy beliefs and the science teaching environment of Danish first-year elementary teachers. *Journal of Science Teacher Education*, 15(1), 25–38.
- Angus, M., Onley, H., Ainley, J., Caldwell, B., Burke, G., & Selleck, R. (2004). *The sufficiency of resources for Australian primary schools*. Canberra: Commonwealth Department of Education, Science and Training.
- Arigbabu, A. A., & Oludipe, D. I. (2010). Perceived efficacy beliefs of prospective Nigerian Science teachers. *Journal of Science Education and Technology*, 19(1), 27–31.
- Avery, L. M., & Meyer, D. Z. (2012). Teaching science as science is practiced: Opportunities and limits for enhancing preservice elementary teachers' self-efficacy for science and science teaching. *School Science and Mathematics*, 112(7), 395–409.
- Aydin, S., & Boz, Y. (2010). Pre-service elementary science teachers' science teaching efficacy beliefs and their sources. *Elementary Education Online*, 9(2), 694–704.
- Azer, S. A. (2001). Problem-based learning. *Saudi Medical Journal*, 22(4), 299–305.
- Bahcivan, E., & Kapucu, S. (2014). Turkish preservice elementary science teachers' conceptions of learning science and science teaching efficacy beliefs: Is there a relationship? *International Journal of Environmental and Science Education*, 9(4), 429–442.
- Bautista, N. U. (2011). Investigating the use of vicarious and mastery experiences in influencing early childhood education majors' self-efficacy beliefs. *Journal of Science Teacher Education*, 22(4), 333–349.
- Bautista, N. U., & Boone, W. J. (2015). Exploring the impact of TeachME™ lab virtual classroom teaching simulation on early childhood education majors' self-efficacy beliefs. *Journal of Science Teacher Education*, 26(3), 237–262.
- Bayraktar, S. (2011). Turkish preservice primary school teachers' science teaching efficacy beliefs and attitudes toward science: The effect of a primary teacher education program. *School Science and Mathematics*, 111(3), 83–92.
- Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The influence of an extensive inquiry-based field experience on pre-service elementary student teachers' science teaching beliefs. *Journal of Science Teacher Education*, 20(3), 199–218.
- Bleicher, R. E. (2004). Revisiting the STEBI-B: Measuring self-efficacy in preservice elementary teachers. *School Science and Mathematics*, 104(8), 383–391.
- Bleicher, R. E. (2009). Variable relationships among different science learners in elementary science-methods courses. *International Journal of Science and Mathematics Education*, 7(2), 293–313.
- Bleicher, R. E., & Lindgren, J. (2005). Success in science learning and preservice science teaching self-efficacy. *Journal of Science Teacher Education*, 16(3), 205–225.
- Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 4–16.
- Brower, D. J. (2012). *Incorporating formative assessment and science content into elementary science methods* (Doctoral dissertation, Montana State University-Bozeman, College of Education, Health and Human Development).
- Burns, R. (2000). *Introduction to research methods* (3rd ed.). Melbourne: Longman Publishers.
- Bursal, M. (2008). Changes in Turkish pre-service elementary teachers' personal science teaching efficacy beliefs and science anxieties during a science method course. *Journal of Turkish Science Education*, 5(1), 99–112.
- Bursal, M. (2010). Turkish preservice elementary teachers' self-efficacy beliefs regarding mathematics and science teaching. *International Journal of Science and Mathematics Education*, 8(4), 649–666.
- Bursal, M., & Paznokas, L. (2006). Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics*, 106(4), 173–180.

- Çakiroglu, J., Çakiroglu, E., & Boone, W. (2005). Pre-service teacher self-efficacy beliefs regarding science teaching: A comparison of pre-service teachers in Turkey and the USA. *Science Educator*, 74(1), 31–41.
- Cannon, J. R., & Scharmann, L. C. (1996). Influence of a cooperative early field experience on preservice elementary teachers' science self-efficacy. *Science Education*, 80(4), 419–436.
- Cantrell, P. (2003). Traditional versus retrospective pretests for measuring science teaching efficacy beliefs in preservice teachers. *School Science and Mathematics*, 103(4), 177–185.
- Cartwright, T. J., & Atwood, J. (2014). Elementary pre-service teachers' response-shift bias: Self-efficacy and attitudes toward science. *International Journal of Science Education*, 36(14), 2421–2437.
- Cone, N. (2009). Community-based service-learning as a source of personal self-efficacy: Preparing preservice elementary teachers to teach science for diversity. *School Science and Mathematics*, 109(1), 20–30.
- Cooper, T. O. (2015). *Investigating the effects of cognitive apprenticeship-based instructional coaching on science teaching efficacy beliefs* (Doctoral dissertation, Florida International University).
- Cross, M. (2010). *The journeys of pre service primary teachers in learning how to teach science: A longitudinal case study*. Charles Sturt University, Bathurst, 1–157. Unpublished Honours Thesis, Charles Sturt University.
- Deehan, M. (2013). *How do I measure up? A longitudinal investigation of a cohort of Australian pre-service primary teachers' science experiences*. Unpublished Honours Thesis. Charles Sturt University, Bathurst, 1–190.
- Duran, E., Ballone-Duran, L., Haney, J., & Beltyukova, S. (2009). The impact of a professional development program integrating informal science education on early childhood teachers' self-efficacy and beliefs about inquiry-based science teaching. *Journal of Elementary Science Education*, 21(4), 53–70.
- Ebrahim, A. H. (2012). The self-efficacy of preservice elementary teachers in Kuwaiti science programs. *Education*, 133(1), 67–76.
- Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences*, 8(3–4), 391–450.
- Englehart, D. (2008). *An exploration of how pre-service early childhood teachers use educative curriculum materials to support their science teaching practices* (Doctoral dissertation, University of Central Florida Orlando, Florida).
- Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics*, 90(8), 694–706.
- Flores, I. M. (2015). Developing preservice teachers' self-efficacy through field-based science teaching practice with elementary students. *Research in Higher Education*, 27(1), 1–20.
- Ford, D. J., Allen, D., Dagher, Z., & Donham, R. (2011). *Reforming science and science education courses for K-8 pre-service teachers: The University of Delaware teacher professional continuum project*. Paper presented at the NSEUS National Conference on Research Based Undergraduate Science Teaching: Investigating Reform in Classrooms, Bryant Conference Center, University of Alabama, Tuscaloosa AL.
- Ford, D. J., Fifield, S., Madsen, J., & Qian, X. (2012). The science semester: Cross-disciplinary inquiry for prospective elementary teachers. *Journal of Science Teacher Education*, 24(6), 1049–1072.
- Gencer, A. S., & Çakiroglu, J. (2007). Turkish preservice science teachers' efficacy beliefs regarding science teaching and their beliefs about classroom management. *Teaching and Teacher Education*, 23(5), 664–675.
- Ginns, I. S., Tulip, D. F., Watters, J. J., & Lucas, K. B. (1995). Changes in preservice elementary teachers' sense of efficacy in teaching science. *School Science and Mathematics*, 95(8), 394–400.

- Goodrum, D., & Rennie, L. (2007). *Australian School Science Education—National Action Plan 2008–2012* (Vol. 1). Canberra: Commonwealth of Australia.
- Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Canberra: Department of Education, Training and Youth Affairs.
- Green, J. L., Camilli, G., & Elmore, P. B. (Eds.). (2006). *Handbook of complementary methods in education research*. Routledge.
- Griffith, G., & Scharmann, L. (2008). Initial impacts of No Child Left Behind on elementary science education. *Journal of Elementary Science Education*, 20(3), 35–48.
- Harris, K. L., & Farrell, K. (2007). The science shortfall: An analysis of the shortage of suitably qualified science teachers in Australian schools and the policy implications for universities. *Journal of Higher Education Policy and Management*, 29(2), 159–171.
- Hechter, R. (2008). *Changes in preservice elementary teachers' personal science teaching efficacy and science teaching outcome expectancies: The influence of context*. Unpublished Doctoral Dissertation, University of North Dakota.
- Hechter, R. (2010). Changes in preservice elementary teachers' personal science teaching efficacy and science teaching outcome expectancies: The influence of context. *Journal of Science Teacher Education*, 22(1), 187–202.
- Hudson, P. (2004). Specific mentoring: A theory and model for developing primary science teaching practices. *European journal of teacher education*, 27(2), 139–146.
- Ivey, T., Colston, N., & Thomas, J. (2015). Bringing space science down to Earth for preservice elementary teachers. *Electronic Journal of Science Education*, 19(2).
- Jabot, M. (2002). The effectiveness of a misconceptions-based approach to the teaching of elementary science methods. *Proceedings of the Pathways to Change International Conference on Transforming Math and Science Education in the K16 Continuum*. Arlington VA: The Science, Technology, Engineering and Mathematics Teacher Education Collaborative (STEMTEC).
- Johnston, J. (2003). Active learning and pre service teacher attitudinal change. *Educational Research Association*, 3–23.
- Kahn, P., & O'Rourke, K. (2005). Understanding enquiry-based learning. In T. Barrett, I. M. Labhrainn, & H. Fallon (Eds.), *Handbook of Enquiry- and Problem- based learning: Irish case studies and international perspectives* (pp. 1–12). Dublin: Centre for Excellence in Learning and Teaching, NUI Galway and All Ireland Society for Higher Education (AISHE).
- Kahraman, S., Yilmaz, Z. A., Bayrak, R., & Gunes, K. (2014). Investigation of pre-service science teachers' self-efficacy beliefs of science teaching. *Procedia-Social and Behavioral Sciences*, 136, 501–505.
- Kenny, J. (2010). Preparing pre-service primary teachers to teach primary science: A partnership-based approach. *International Journal of Science Education*, 32(10), 1267–1288.
- Kervin, L., Wilma, V., Herrington, J., & Okely, T. (2006). *Research for educators*. Melbourne: Cengage learning Australia.
- King, K. P., & Wiseman, D. L. (2001). Comparing science efficacy beliefs of elementary education majors in integrated and non-integrated teacher education coursework. *Journal of Science Teacher Education*, 12(2), 143–153.
- Knaggs, C. M., & Sondergeld, T. A. (2015). Science as a learner and as a teacher: Measuring science self-efficacy of elementary preservice teachers. *School Science and Mathematics*, 115(3), 117–128.
- Lawrance, G. A., & Palmer, D. A. (2003). *Clever teachers, clever sciences: Preparing teachers for the challenge of teaching science, mathematics and technology in 21st Century Australia*. Canberra: Australian Government, Department of Education, Science and Training: Research Analysis and Evaluation Group.
- Leonard, J., Barnes-Johnson, J., Dantley, S. J., & Kimber, C. (2011). Teaching science inquiry in urban contexts: The role of elementary preservice teachers' beliefs. *The Urban Review*, 43(1), 124–150.

- Lewthwaite, B., Murray, J., & Hechter, R. (2012). Revising teacher candidates' views of science and self: Can accounts from the history of science help?. *International Journal of Environmental and Science Education*, 7(3).
- Logerwell, 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).
- Luera, G. R., & Otto, C. A. (2005). Development and evaluation of an inquiry-based elementary science teacher education program reflecting current reform movements. *Journal of Science Teacher Education*, 16(3), 241–258.
- Mashnad, P. F. (2008). *An alternate approach to pre-service teachers' misconceptions about biology subject* (Doctoral dissertation, University of Texas at Dallas).
- McDonnough, J. T., & Matkins, J. J. (2010). The role of field experience in elementary preservice teachers' self-efficacy and ability to connect research to practice. *School Science and Mathematics*, 110(1), 13–23.
- McKinnon, M., & Lamberts, R. (2013). Influencing science teaching self-efficacy beliefs of primary school teachers: A longitudinal case study. *International Journal of Science Education, Part B*, (ahead-of-print), 1–23.
- Morrell, P. D., & Carroll, J. B. (2003). An extended examination of preservice elementary teachers' science teaching self-efficacy. *School Science and Mathematics*, 103(5), 246–251.
- Mulholland, J., Dorman, J. P., & Odgers, B. M. (2004). Assessment of science teaching efficacy of preservice teachers in an Australian university. *Journal of Science Teacher Education*, 15(4), 313–331.
- Naidoo, K. (2013). Transforming beliefs and practices: Elementary teacher candidates' development through shared authentic teaching and reflection experiences within an innovative science methods course. *Dissertation Abstracts Internal*, 74(10), 256.
- Newsome, D. L. (2003). The efficacy beliefs of preservice science teachers in professional development school and traditional school settings. *Dissertation Abstracts International*, 64(5), 1588–1694.
- NSW Government—Department of Education and Communities. (2011). *2011 Workforce plan—for school teachers in NSW public schools*. Sydney: NSW Government—Department of Education and Communities.
- Olgan, R., Alpaslan, Z. G., & Öztekin, C. (2014). Factors influencing pre-service early childhood teachers' outcome expectancy beliefs regarding science teaching. *Egitim Ve Bilim-Education and Science*, 39(173), 288–298.
- Ozdelik, Z., & Bulunuz, N. (2009). The effect of a guided inquiry method on pre-service teachers' science teaching self-efficacy beliefs. *Turkish Science Education Journal*, 6(2), 24–42.
- Palmer, D. (2006a). Durability of changes in self-efficacy of preservice primary teachers. *International Journal of Science Education*, 28(6), 655–671.
- Palmer, D. (2007). Practices and innovations in Australian science teacher education programs. *Journal of Science Education*, 38(2), 167–188.
- Palmer, D. H. (2006b). Sources of self-efficacy in a science methods course for primary teacher education students. *Research in Science Education*, 36(4), 337–353.
- Park, S. (1996). *Development and validation of the Korean science teaching efficacy beliefs instrument (K-STEBI) for prospective elementary school teachers* (Doctoral dissertation, Pennsylvania State University).
- Peters-Burton, E. E., & Hiller, S. E. (2013). Fun science: The use of variable manipulation to avoid content instruction. *Journal of Science Teacher Education*, 24(1), 199–217.
- Plourde, L. A. (2002). The influence of student teaching on pre-service elementary teachers' science self-efficacy and outcome expectancy beliefs. *Journal of Instructional Psychology*, 29(4), 245–253.
- Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education*, 80, 283–315.

- Richardson, G. M., & Liang, L. L. (2008). The use of inquiry in the development of preservice teacher efficacy in mathematics and science. *Journal of Elementary Science Education*, 20(1), 1–16.
- Richardson, G. M., Liang, L. L., & Wake, D. G. (2014). Examining the durability of environmental education self-efficacy beliefs in preservice teaching. *Applied Environmental Education & Communication*, 13(1), 38–47.
- Ritter, J. M. (1999). *The development and validation of the self-efficacy beliefs about equitable science teaching and learning instrument for prospective elementary teachers* (Doctoral dissertation, The Pennsylvania State University).
- Rogers, G. & Watters, J. J. (2002). Global perspectives of science education: Successes and challenges of a pilot project. Paper presented at the Annual Meeting of the Australasian Science Education Research Association Conference, Melbourne, July 9–12, 2002.
- Sağkes, M., Flevaras, L. M., Gonya, J., & Trundle, K. C. (2012). Preservice early childhood teachers' sense of efficacy for integrating mathematics and science: Impact of a methods course. *Journal of Early Childhood Teacher Education*, 33(4), 349–364.
- Sarikaya, H., Çakiroğlu, J., & Tekkaya, C. (2005). Self-efficacy, attitude and science knowledge. *Academic Exchange Quarterly*, 9(4), 38–42.
- Sasser, S. K. (2014). *Effect of structure in problem based learning on science teaching efficacy beliefs and science content knowledge of elementary preservice teachers*. (Doctoral dissertation, Southern Illinois University).
- Scharmann, L. C., & Orth Hampton, C. M. (1995). Cooperative learning and preservice elementary teacher science self-efficacy. *Journal of Science Teacher Education*, 6(3), 125–133.
- Schmidt, D. L., Saigo, B. W., & Stepan, J. I. (2006). *Conceptual change model: The CCM handbook*. Saiwood Publications.
- Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education*, 82(5), 553–568.
- Scott, C. S. (2013). *Inquiry, efficacy, and science education*. (Doctoral dissertation, Georgia Southern University, United States, Georgia). Retrieved February 3, 2014, from <http://digitalcommons.georgiasouthern.edu/etd>
- Serin, K., & Bayraktar, Ş. (2014). Pre-service classroom teachers' science teaching efficacy beliefs and their locus of control status. In *Conference proceedings. New perspectives in science education* (p. 319). liberiauniversitaria. it Edizioni.
- Shroyer, M. G., Wright, E. L., & Ramey-Gassert, L. (1996). An innovative model for collaborative reform in elementary school science teaching. *Journal of Science Teacher Education*, 7(3), 151–168.
- Sindel, K. D. (2010). *Can experiential education strategies improve elementary science teachers' perceptions of and practices in science teaching?* (Doctoral dissertation, Lindenwood University).
- Slater, S. J., Slater, T. F., & Shaner, A. (2008). Impact of backwards faded scaffolding in an astronomy course for pre-service elementary teachers based on inquiry. *Journal of Geoscience Education*, 56(5), 408.
- Slavin, R. (1991). Synthesis of research on cooperative learning. *Educational Leadership*, 48(5), 71–82.
- Soprano, K., & Yang, L. L. (2013). Inquiring into my science teaching through action research: A case study on one pre-service teacher's inquiry-based science teaching and self-efficacy. *International Journal of Science and Mathematics Education*, 11(6), 1351–1368.
- Sunger, M. (2007). *An analysis of efficacy beliefs, epistemological beliefs and attitudes towards science in preservice elementary science teachers and secondary science teachers* (Doctoral dissertation, Middle Easter Technical University).
- Suter, W. N. (2006). *Introduction to educational research: A critical thinking approach*. Thousand Oaks: Sage Publications.
- Swars, S. L., & Dooley, C. M. (2010). Changes in teaching efficacy during a professional development school-based science methods course. *School Science and Mathematics*, 110(4), 193–202.

- Tekkaya, C., Çakiroglu, J., & Ozkan, O. (2004). Turkish pre-service science teachers' understanding of science and their confidence in teaching it. *Journal of Education for Teaching*, 30(1), 57–68.
- Templeton, C. K. (2007). *The impact of a museum-based science methods course on early childhood/elementary pre-service teachers' self-efficacy and ability to develop curriculum using a constructivist approach*. Florida Atlantic University.
- Ting, W., & Albion, P. R. (2014). Remote access laboratories enhancing STEM education. In *Proceedings of the 31st Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (ASCILITE 2014)* (pp. 579–583). Macquarie University.
- Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School Science and Mathematics*, 100(7), 374–379.
- Tytler, R. (2007). *Re-imagining science education: Engaging students in science for Australia's future*. Camberwell, Victoria: Australian Council for Educational Research.
- Tytler, R. (2009). School innovation in science: Improving science teaching and learning in Australian schools. *International journal of science education*, 31(13), 1777–1809.
- Urban-Woldron, H. (2014). Preparing prospective elementary teachers to teach science: A challenge for teacher education. *Open Online Journal for Research and Education*, 11(2).
- Velthuis, C., Fisser, P., & Pieters, J. (2014). Teacher training and pre-service primary teachers' self-efficacy for science teaching. *Journal of Science Teacher Education*, 25(4), 445–464.
- Vygotsky, L. (1977). The development of higher psychological functions. *Soviet Psychology*, 16(1), 60–73.
- Wagler, R. (2011). Out in the field: Assessing the impact of vicarious experiences on preservice elementary science teaching efficacy. *Electronic Journal of Science Education*, 15(2), 1–28.
- Watters, J. J. (2007, October 29–31). Problem based learning in pre-service elementary science teacher education: Hostile territory. *Proceedings of the PBL Conference on Problem-Based Learning in Undergraduate and Professional Education*. Birmingham, Alabama (pp. 1–10). Retrieved October 15, 2008, from <http://www.eprints.qut.edu.au>.
- Watters, J. J., & Ginns, I. S. (1999). *Setting the environment for life-long learning: Collaborative and authentic learning practices in primary science teacher education*. Paper presented at the International Research Network “PACT” Conference, Chinese University of Hong Kong.
- Watters, J., & Ginns, I. (2000). Developing motivation to teach elementary science: Effect of collaborative and authentic learning practises in preservice education. *Journal of Science Teacher Education*, 11(4), 301–321.
- Wenner, G. (1995). Science knowledge and efficacy beliefs among preservice elementary teachers: A follow-up study. *Journal of Science Education and Technology*, 4(4), 307–315.
- Wenner, G. (2001). Science and mathematics efficacy beliefs held by practicing and prospective teachers: A 5-year perspective. *Journal of Science Education and Technology*, 10(2), 181–187.
- Wilson, S. (2012). Drivers and blockers: Embedding education for sustainability (EFS) in primary teacher education. *Australian Journal of Environmental Education*, 28(01), 42–56.
- Wingfield, M. E., & Ramsey, J. (1999). *Improving science teaching self-efficacy of elementary pre-service teachers*. Paper presented at the Association for the Education of Teachers in Science Annual Meeting in Austin, TX.
- Yang, E., Anderson, K. L., & Burke, B. (2014). The impact of service-learning on teacher candidates' self-efficacy in teaching STEM content to diverse learners. *International Journal of Research on Service-Learning in Teacher Education*, 2, 1–46.
- Yilmaz, H., & Çavaş, P. (2008). The effect of the teaching practice on pre-service elementary teachers' science teaching efficacy and classroom management beliefs. *Eurasia Journal of Mathematics, Science and Technology Education*, 4(1), 45–54.
- Yilmaz-Tuzun, O., & Topcu, M. S. (2008). Relationships among preservice science teachers' epistemological beliefs, epistemological world views, and self-efficacy beliefs. *International Journal of Science Education*, 30(1), 65–85.

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

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