Influencing Science Teaching Self-Efficacy Beliefs of Primary School Teachers: A longitudinal case study

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The science teaching self-efficacy beliefs of primary school teachers influence teaching practice. The purpose of this research was to determine if informal education institutions, such as science centres, could provide professional development that influences the science teaching self-efficacy beliefs of pre-service and in-service primary school teachers. A cohort of eight final-year pre-service teachers and 13 in-service teachers in Australia participated in this research over a period of 18 months. The results of this research showed that four hours of professional development workshops produced by science centres were capable of increasing the science teaching self-efficacy of all but three participants, with observable effects for at least 11 months after the completion of the workshops. The participants identified the workshops as a positive influence on their science teaching, and an important source of confidence and motivation. This project showed that the informal education sector can contribute to achieving positive reforms within science education, but only if the context in which teachers must operate is taken into account and reform efforts adapted accordingly. The informal science education sector could be the key to achieving long lasting reform in science education where other, formal measures have failed. Further studies are required to look at how places like science centres and museums can work with teacher educators, particularly in universities, to assist in the training of new teachers in science.

Keywords: *Informal education; Primary teachers; Science teaching; Self-efficacy beliefs*

Introduction

Teachers are the greatest influence on student outcomes and achievement (Rowe, 2002), yet Australian primary school teachers feel under-prepared to teach

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science and many lack the confidence to try (Goodrum, Hackling, & Rennie, 2001). But this problem is by no means limited to the Australian context. A study in Turkey of the beliefs of pre-service and in-service teachers found that teachers generally feel they do not have a sound understanding of science themselves (Irez, 2006). A later study further found Turkish teachers felt under-prepared to teach science (Bursal, 2008), reiterating findings of similar studies with teachers in the UK (Murphy & Beggs, 2005) and in the USA (Dorph et al., 2007). Teacher preparation and their qualifications in the subjects they teach are strongly related to student achievement (Darling-Hammond, 2000). An earlier study of science teaching in the UK found teachers lacked the confidence to carry out simple science investigations with their classes (Murphy & Beggs, 2005). Under-prepared teachers with previous, potentially negative, experiences in science could create teachers who are more likely to avoid teaching science or teach it poorly (Palmer, 2008).

A comparative study of primary science teaching in Ireland, the UK and Australia found that although the majority of students are enthusiastic about learning science, particularly using hands-on activities, they 'are not necessarily relating their school science experiences to the wider world or to future aspirations' (Varley, Murphy, & Veale, 2008, p. 8). One explanation offered by the report is that the opportunities to engage in student-centred activities like hands-on learning may not be regular, or in some cases even offered.

Smith and Neale (1989) propose that teachers have strong beliefs about what science is, and how it should be taught. Teachers hold beliefs about their profession and practice, including their own beliefs about their ability to teach and to achieve positive outcomes for their students, what Bandura (1995) terms science teaching self-efficacy. Unless the beliefs of teachers about teaching are addressed in reform efforts, enduring change will not occur (Lumpe, Haney, & Czerniak, 2000; Pint'o, 2004).

An effective way of influencing teachers' beliefs and practice is through professional development (PD). But traditional science-based PD may not always be available, and does not always work. This article examines how non-traditional PD offered by science centres contributes to supporting pre-service and in-service primary school teachers in their science teaching.

Professional Development of Teachers as a Means of Science Education Reform

Teachers 'need to be learners and experience their viable knowledge for change in beliefs' (Mansour, 2009, p. 38). This echoes Watters and Ginns (2000, p. 317) who found that 'student-centred instructional strategies ... can change pre-service teachers' beliefs about their ability to teach science'. Placing the teacher in the role of the student during PD is essential to motivate and affect change (Watters & Ginns, 2000). The use of active learning opportunities is thus essential and a characteristic of high quality PD (Desimone, Porter, Garet, Yoon, & Birman, 2002). In Australia, most PD offerings are short-term or single events (McRae, Ainsworth, Groves, Rowland, & Zbar, 2001). Many argue that single-event or 'one-off' PD cannot have lasting effects (Tytler, Osborne, Williams, Tytler, & Cripps Clark,

2008) and advocate longer-term, sequential programmes (Desimone, et al., 2002). Continuing PD is necessary for pre-service and beginning teachers as well as for in-service teachers. But ongoing PD rarely happens in practice (McRae et al., 2001) often due to the difficulty in attracting and retaining teachers who already have many ongoing demands on their time.

Collaborative PD can greatly enhance teacher success (Garet, Porter, Desimone, Birman, & Yoon, 2001; Watson, Steele, Vozzo, & Aubusson, 2007) especially where communities of learners are from the same school environment and have already established rapport and trust, making group work more effective (Penlington, 2008). Established groups working together is also an effective means of gaining positive responses to reform efforts (Judson & Lawson, 2007). Continuing PD offered to the same cohort within one school over time may prove more effective than PD for teachers who are unfamiliar with each other (Desimone et al., 2002).

Measuring PD impacts—on both teachers and students—can be problematic as effects are not often apparent (McRae et al., 2001). Where impacts have been successfully measured, the results for science-based PD are inconsistent. For example, Desimone et al. (2002) found no effects for PD duration, and Hilliard (1997) found science PD was less successful than for other subjects. Perera (2010) however found that one-day science PD workshops positively influenced practising teachers by increasing their confidence to experiment with prescribed hands-on activities and develop their own demonstrations. This study further explores the potential of PD using hands-on activities, as PD may be the best chance of achieving science education reform, where there are no other options (Chia-Ju, Jack, & Houn-Lin, 2008).

Researchers advocate PD involving organisations external to the school (Aubusson, Griffin, Sawle, & Vassila, 2010; Commonwealth of Australia, 2006; Hoban, 1997) as this offers novel perspectives and sees teachers learning from specialists in their field. It also encourages teacher communities to reflect on their group practice. The challenge is to ensure such PD is ongoing and affordable and takes into account workplace context. Teachers like science-based PD provided by outside experts and they consider science centres have such expertise (Aubusson et al., 2010).

Informal Education Institutions and PD

Informal science education providers, like science centres, are well positioned to help reform science education, particularly as they highlight science's relevance to everyday life (Holstermann, Grube, & Bögeholz, 2010). Science centres predominantly apply constructivist approaches to education, emphasising hands-on activities and active visitor engagement (So & Watkins, 2005). This is an approach that teachers regard as a characteristic of 'high quality' PD (Desimone et al., 2002).

'Hands-on' approaches to science are also important for the enhancement and maintenance of pre-service teachers' self-efficacy (Palmer, 2006b; Schoon & Boone, 1998; Watters & Ginns, 2000). Successful experiences with science can increase teachers' confidence (Woolfolk Hoy & Burke Spero, 2005), which should translate to better science teaching practice (Nye & Thigpin, 1993).

In a study examining PD offered by a science centre in the USA, participating in-service teachers felt that the hands-on nature of the workshops helped to increase science content knowledge and change their instructional methods (Melber & Cox-Peterson, 2005). Yet only limited data on the impacts of informal education on teacher PD exist (ecsite UK, 2008; Garnett, 2002). This research therefore examines whether combining the characteristics of effective PD (Desimone et al., 2002; Garet et al., 2001), with informal science education PD can inspire programmes that have an impact on teachers' beliefs and subsequent science teaching.

Primary School Teachers' Science Training and Self-Efficacy

Pre-service teachers have entrenched beliefs about science and teaching (Friedrichsen & Dana, 2003; Schwarz & Gwekwerere, 2007) largely determined by their own experiences as students (Settlage, 2000). Yet this is often not addressed in formal teacher training (Palmer, 2008).

The key to training good science teachers lies in fostering positive beliefs about science and their ability to teach it (Tytler, 2003). Numerous studies have examined the science beliefs of in-service teachers, their science teaching self-efficacy and how PD can improve it. However, few studies on final-year pre-service teachers and their transition to teaching in schools exist, even though this is a crucial time for belief formation and change (Luft, 2007).

Ginns, Tulip, Watters, and Lucas (1995) note that pre-service training rarely increases science teaching self-efficacy. Even when it does, Palmer (2006a) adds that due to the typical education degree structure often a year elapses between pre-service teachers completing science education subjects and finishing their teaching degree, likely eroding any self-efficacy gains those subjects may have inspired. Research on these early years would aid our understanding of influences on new teachers, and how these influences manifest in their beliefs and behaviour (Chan, 2008). Mansour (2009, p. 43) asserts that understanding teachers' beliefs would provide a good framework for future reform efforts and in order to understand 'it is necessary to carry out a longitudinal study with pre-service and in-service science teachers'.

The Evolution of Self-Efficacy and Its Application to Research in Science Teaching

The concept of self-efficacy was first developed by Rotter (1966) and focused on 'Locus of Control'. He proposed people believe either they personally influence outcomes that affect them (internal locus of control) or that external, environmental factors are responsible (an external locus of control). Bandura (1977) developed a second strand of self-efficacy, grounded in social learning theory. Here self-efficacy has two elements: 'efficacy expectation' (belief in one's ability to achieve a desired outcome or behaviour); and 'outcome expectancy' (belief that the achievement of the desired behaviour will have a desirable outcome). Bandura (1995) describes teaching self-efficacy as a teacher's belief about their ability to teach and produce positive outcomes for their students. Tschannen-Moran, Woolfolk Hoy, and Hoy (1998)

distinguish self-efficacy from other conceptions of self, like self-esteem, as it pertains to a specific task. It 'has to do with self-perception of competence rather than the actual level of competence' (Tschannen-Moran et al., 1998, p. 210).

Bandura (1997) compared his self-efficacy theory with that stemming from Rotter's work on locus of control. This saw the two constructs measuring different things. Self-efficacy considered a person's perception of their own ability to produce certain actions, while locus of control describes a person's beliefs about the ability of actions to affect outcomes. Bandura found that the two concepts have little to no relationship, with perceived self-efficacy a much stronger predictor of behaviour than locus of control (Tschannen-Moran et al., 1998). Supporting this, Gencer and Cakiroglu (2007, p. 664) assert that self-efficacy beliefs of teachers have 'emerged as one of the few teacher characteristics that consistently relates to teaching and learning over the past 25 years'. For this reason, Bandura's theory of self-efficacy forms the theoretical basis for this study.

Gibson and Dembo (1984) developed the teaching efficacy scale (TES) to measure general teaching efficacy. Enochs and Riggs (1990) modified this to create the science-specific science teaching efficacy belief instrument (STEBI). This instrument was specifically designed to measure the self-efficacy beliefs of in-service primary teachers (STEBI A). They later modified this to measure the self-efficacy beliefs of pre-service teachers as well (STEBI B). In both instruments, the questions were grouped according to Bandura's two factors contributing to efficacy: 'Personal Science Teaching Efficacy Belief' (PSTE) and 'Science Teaching Outcome Expectancy' (STOE).

The validity (Riggs & Enochs, 1990) and reliability (de Laat & Watters, 1995; Ramey-Gassert, 1994) of the STEBI A have been extensively tested. The STEBI B was also validated by its developers (Enochs & Riggs, 1990) and in numerous studies of science teaching efficacy of pre-service teachers (Bleicher, 2004). Ginns et al. (1995) express their confidence in the validity and reliability of the STEBI B for Australian schools, stating it could readily measure the effects of changes in science teaching self-efficacy.

The STOE scale has attracted criticism as it attempts to measure outcomes controlled by the environment, rather than the teacher themselves (Dellinger, Bobbett, Oliver, & Ellet, 2008). Therefore, studies of teacher self-efficacy need to consider the context of the beliefs in order to maximise their usefulness. Palmer (2006a) recommends conducting interviews in conjunction with the use of the STEBI instruments to allow for data comparison and verification, a recommendation that is followed in this study.

Research Problem

This research aimed to determine if short PD workshops produced by science centres positively influenced the science teaching self-efficacy of primary school teachers and, if there was an influence, to what extent this was affected by the amount of experience a teacher had.

This study examined teachers already working in schools and those in transition from pre-service to in-service. Pre-service teachers' beliefs are more likely to be malleable, according to the literature; however this study also examined the beliefs of experienced teachers to see if PD can influence them. The resilience and duration of any changes in the self-efficacy beliefs of the participating teachers were also explored. The research questions that guided this study were:

- (1) Do short PD workshops produced by science centres have any effect on teachers' science teaching self-efficacy?
- (2) Do short PD workshops produced by science centres affect pre-service teachers differently from in-service teachers?
- (3) How do teachers' beliefs and previous science experiences influence their perception of science, and their science teaching self-efficacy?

Method

Participants

Eight pre-service teachers in the final year of their degree and 13 in-service teachers with varying levels of experience participated in this year-long study (Table 1). All were from southeastern Australia, from the Australian Capital Territory (ACT) or New South Wales (NSW). Three participants were male, the rest were female. Pseudonyms are used in the presentation of these results.

Workshops

Each participant completed a series of four workshops developed by a science centre, on topics such as fluids, climate change, music and sound, and pressure. The PD workshops had been developed by a local science centre, which has an excellent reputation amongst the local teaching community. Its position as an 'outside expert' lent credibility to the PD on offer (Aubusson et al., 2010).

Each workshop featured up to 10 hands-on activities that used simple, every day materials to demonstrate scientific principles. An example of the kinds of activities used in each workshop is shown in Table 2. Although all four topics could be presented within one, longer workshop offered as a single event to teachers, the decision was made to run the topics in separate, shorter workshops, providing repeated opportunity and exposure for participants over time.

The workshops incorporated recommended best practice for teaching and PD. One activity from the workshops will be described to illustrate this.

An activity in the fluids workshop challenged the participants to float a paperclip in a container filled with water. The materials used were easily available from home, work or supermarkets, increasing the personal relevance of the workshop materials to the participants by building knowledge based upon that which is familiar (Stockmayer, Durant, & Cerini, 2011) and highlighting the link to real life (Holstermann et al., 2010).

Table 1. Demographics of study participants

Cohort	Participant	Age range	Number of years teaching	Science background	Additional contextualising information (where relevant to results)
ACT in-service	Paula	45–50	20+	None	Most fearful of science
	Valerie	51–56	20+	None	Team teaches with Brian
	Kerrie	51–56	20+	None	Limited teaching between sample periods 3 and 4 due to illness
	Elizabeth	51–56	20+	None	—
	Lorraine	51–56	20+	None	—
	Brian	63+	20+	None	Acting deputy principal
NSW in-service	Susan	—	15–20	Some units in postgraduate course	Most science positive participant
	Hayley	57–62	20+	None	Support teacher
	Simone	39–44	15–20	Basic science/biology unit in Dip Ed	Changed schools between sample periods 3 and 4
	Tanya	27–32	4–6	None	—
	Lisa	27–32	4–6	None	—
	Paul	51–56	1–3	B. Ed with Environmental Studies and Science II	Changed schools after sample period 2; works in special needs school
	Anita	45–50	20+	One subject on Birds of Australia	Changed schools between sample periods 3 and 4
	Anthea	27–32	<1	Two science & technology units as part of Bachelor of Primary Teaching	—
	Kendra	21–26	<1	As above	—
	Jaeda	21–26	<1	As above	—
Pre-service	Kate	21–26	<1	As above	—
	Peter	51–56	<1	As above	Teaching in Torres Strait in sample period 4
	Vanessa	21–26	<1	As above	Informal science education experience
	Lauren	21–26	<1	As above	—
	Sam	21–26	<1	As above	Teaching in UK in sample period 4

Table 2. Overview of workshop activities

Workshop theme	Topics	Example activities	Concept
Week 1 Air and water pressure	Forces, pressure	Make an air cannon out of an empty tin can, rubber bands and balloons. Use the air cannon to hit paper targets or blow out candles Make 'pop-ups' (scenes or animals) using syringes, air, water and tubing	Pressure Pneumatics, hydraulics
Week 2 Sound and music	Vibrations, pitch, amplification	Make a musical instrument from PVC piping, balloons and masking tape Make a 'musical straw' Experiment with straw length and pitch	Vibrations Vibrations, pitch
Week 3 Fluids	Surface tension, viscosity, cohesion, density, floating, sinking	Float a light object (like a paperclip) on top of water Make a star out of toothpicks and water	Surface tension Cohesion, capillary action
Week 4 Climate change	Greenhouse effect, climate research data collection methods (i.e. ice cores), effects of temperature change on carbon dioxide storage, sea levels	Fill a glass full of ice cubes. Then completely fill the glass with water so the surface of the water is in line with the top of the glass. Sit in a warm place and observe what happens to the water level as the ice cubes melt Make an 'ice core' sample using a potato Cut lengthwise into sections and place a different drop of food colouring on each. Stack layers on top of each other and using an apple corer take a 'sample'	Influence of continental versus sea ice melting on sea level Stratification of ice, how scientists use ice cores to interpret atmospheric information

Participants made initial attempts based on their assumptions of what should work—carefully placing the paperclip using their fingers. This method disrupts the surface tension of the water too much, so the paperclip sinks. Based on their

observations, participants refined their ideas and developed new methods of placing a paperclip on the surface of the water, without compromising the surface too much. This ranged from shaping another paperclip to use to lower a paperclip onto the surface, or using two paperclips like tweezers to place a third. Discussions between participants of how best to successfully float the paperclip lead to new understandings being developed and explored. This fostered collaboration as the participants began working together to solve the problem, explain their ideas and ultimately demonstrate their success to others. Ideas of how this activity could be incorporated, and extended, in the classroom were also shared.

As all participants in each of the different groups were colleagues, conversation and sharing was free-flowing (as per Penlington, 2008). By experiencing the activity themselves, participants gained insight into how their own students would likely approach the task, and in what areas students could potentially require clarification. This process models the inquiry-based pedagogy that participants could use to present this activity in class, which focuses on developing students' skills to question, predict, plan and conduct explorations, analyse results and communicate findings to others. All the workshop activities incorporated these characteristics.

Refreshments were provided, and a relaxed, informal atmosphere was fostered. Participants were able to move through the activities at their own pace, with minimal instruction and interruption from the researcher, unless assistance was requested. Workshops ran for approximately one hour, over a period of between 5 and 10 weeks, with the full series of four workshops completed in under five hours for each cohort. At the end of each workshop, participants were given copies of the workshop materials to facilitate the transfer of workshop activities and concepts to the classroom. After the series, the only contact between the researcher and participants involved organising the next round of data gathering. Participants could contact the researcher for information and materials at any stage—an invitation taken up by only two pre-service teachers.

Data Collection

Participants completed an initial STEBI survey (STEBI A for in-service, STEBI B for pre-service) prior to the workshops providing an efficacy belief baseline (Period 1). As there have been some criticisms of the validity of the two scales used in the original STEBI instruments (Henson, Kogan, & Vacha-Haase, 2001; Tschannen-Moran et al., 1998), Bleicher's modified version of the STEBI B was used in this study (Bleicher, 2004). STEBI surveys were administered again immediately after the workshop series (Period 2), then at four months (Period 3) and 11 months after completion (Period 4). At Period 4, the pre-service participants were given the STEBI A instead of the STEBI B, as they had become in-service. The purpose and background of the STEBI instrument and what it measured was explained to participants only once, during Period 1, to minimise the influence of repeated measures and of the potential for the research itself to be an 'impact'. Participants were offered further clarification during subsequent periods but none requested any.

Figure 1. Research method timeline

All participants were interviewed at periods 3 and 4. The interviews were semi-structured examining participants' prior science experiences, their fears about teaching, in general and specifically science teaching (Figure 1).

Data Analysis

STEBI. The STEBI-A has 25 items, the STEBI-B 23 items, each using a five-point Likert response scale. The STEBI (A and B) comprise two scales: PSTE and STOE. Items reflecting the scales appear randomly throughout the instruments. For each instrument, the PSTE and STOE scales are added, generating a separate score for both scales with a range of 13–65 for the PSTE scale and 12–60 in the STOE scale (10–50 in the STEBI B). A higher score represents higher self-efficacy (PSTE) or outcome expectancy (STOE) beliefs. The results collected at Period 4 (STEBI A) and Period 3 (STEBI B) were analysed for internal reliability using Cronbach's alpha.

Additional analyses were conducted on cohort level data to determine if differences manifested between pre-service and in-service groups or across all groups generally. Research period and cohort effects on scores were tested using a linear mixed effects model using an AR(1) correlation structure. Research period and cohort were the fixed effects in the model, and individual was the random effect. Research period and cohort interactions were also tested. *p*-values less than or equal to .05

were considered statistically significant. The IBM Statistical Package for Social Science (SPSS—version 16 and version 19) was used for all analyses.

Semi-structured interviews. Interviews were conducted face-to-face and recorded. Each interview ran for between 10 and 20 minutes. The recordings were then transcribed verbatim and analysed for common words and themes, from which a coding system was developed, allowing the data to be compiled into categories. For example, any response that mentioned books, specialist staff assistance or equipment was coded as resources. Coded interviews were then examined at individual and group levels.

Interview responses were compared for the two interview periods, looking for any attitudinal changes of the participant towards science or teaching. Similarities and differences between pre-service and in-service participant groups were also identified. Participant responses in the interviews were then examined in conjunction with the data collected through the two survey instruments.

Results

The following results include qualitative data from interviews and the results from the STEBI surveys. Results are organised and presented under the three major research questions examined in this study.

Validity of STEBI Survey Results

Analyses of the internal reliability of the STEBI A returned Cronbach's alphas of 0.914 for the PSTE and 0.776 for the STOE scale. Items 9 and 20 (both from the STOE scale) had a corrected item total correlation value of 0.3 and were excluded from all analyses of STEBI A (see Robinson, Shaver, & Wrightsman, 1991). This changed the range of the STOE scale to 10–50. With these excluded, the STOE scale Cronbach's alpha was 0.814, values congruent with those reported by the instrument developers at 0.92 for the PSTE and 0.77 for the STOE, respectively (Riggs & Enochs, 1990).

The STEBI B Cronbach alpha values were 0.899 (PSTE) and 0.864 (STOE), with none of the items showing a corrected item total correlation value below 0.3. No items were excluded. Once more, alpha values were comparable (0.90 for the PSTE scale and 0.76 for the STOE) to those of the STEBI B developers (Enochs & Riggs, 1990).

The pre-test means for the STEBI A were 46.58 and 33.51 (for the PSTE and the STOE scales, respectively), comparable to larger studies in the field (de Laat & Watters, 1995; Riggs & Enochs, 1990). Pre-test PSTE and STOE means from the pre-service participants (STEBI B) were 46.38 and 36.06, respectively, and are similar to comparable Australian studies (e.g. Palmer, 2006a; Watters & Ginns, 2000).

Research question 1: Do short PD workshops produced by science centres have any effect on teachers' science teaching self-efficacy?

The background and experience of participants are in Table 1. Most in-service teachers had more than 20 years of experience. At both interviews, participants were asked if they had attended any other form of science-based PD. Of the 21 participants, only one ('Anita') had, indicating that the workshops of this study were the only formal science-based PD most participants received during our study.

All ACT in-service teachers showed increased PSTE scores between Period 1 and Period 4, except Paula (Table 3). Interview responses suggested participants felt the workshops contributed to this increase through the use of hands-on activities and the collegial atmosphere:

I really enjoyed those sessions [the workshops]. There was a lot of talk and maybe we should have done a bit more experimenting than we did, but it kind of gave an impetus to the seven of us who did it without which we would be more, well, I speak for myself, would be more backing off from science than turned out to be the case, given the fact that you did this [workshop] with us. (Brian, interview, period 4)
I've certainly used some of [the workshop activities] in my science program and I've put more in my program too. Just the ones [from the workshop] .... (Lorraine, interview, period 3)

Kerrie and Lorraine in particular showed large increases in their PSTE scores. These increases were matched by a corresponding decrease in STOE scores (Table 3).

All NSW in-service participants had higher PSTE scores at period 4 than at period 1. Anita and Simone had changed schools between periods 3 and 4. Of the NSW in-service teachers, all but one (Tanya) increased their PSTE scores immediately after the workshops (period 2). Four of the six NSW in-service participants had lower STOE scores at period 4 than at period 1, despite all having higher PSTE scores over the same timeframe. For some, the initial increase in their PSTE scores was accompanied by a decrease in their STOE scores between periods 1 and 2, similar to the results seen in the ACT cohort.

Immediately after the workshops (period 2), all pre-service participants except Peter (whose scores were largely static) increased PSTE scores (Table 3). Five of eight pre-service participants identified the workshops as a positive influence. Key strengths of the workshops were seen to be the hands-on activities and the greater understanding of science participants gained by participating. Typical comments included:

I think that the workshops were fantastic and I really hope that that could become a greater focus in university. You explained how it all made sense and the university hadn't done that. (Jaeda, interview, period 4)
The [workshops] we did with you were the first actual, interactive, useful experiments that I have had as a teacher. (Sam, interview, period 3)
Run more workshops, please! Seriously, the unis are failing to provide proper science units and we're just going to have this generation of teachers that are ... just not going to teach science. I'm still hesitant and I had the workshop that you [ran]. If I was a student and I hadn't done the workshops that you did I doubt that I'd be teaching science. (Kate, interview, period 4)

Table 3. STEBI scores from each sample period for all participants

Cohort	Participant	Teaching experience (years)	Period 1		Period 2		Period 3		Period 4	
			PSTE	STOE	PSTE	STOE	PSTE	STOE	PSTE	STOE
ACT in- service	Paula	20+	34	36	31	35	39	34	34	45
	Valerie	20+	40	41	44	28	44	36	50	35
	Kerrie	20+	30	34	49	35	46	34	52	29
	Elizabeth	20+	32	43	40	42	39	47	43	47
	Lorraine	20+	32	49	48	44	37	47	46	44
	Brian	20+	49	41	47	47	48	44	54	48
NSW in- service	Susan	15-20	58	44	65	45	62	42	61	37
	Hayley	20+	42	46	43	46	45	44	45	45
	Simone	15-20	46	45	57	50	51	36	48	39
	Tanya	4-6	53	38	53	34	57	39	56	41
	Lisa	4-6	40	39	47	34	52	40	50	38
	Anita	20+	42	44	43	39	42	44	47	46
Pre-service	Paul	1-3	48	39	52	42	52	40	50	36
	Anthea	<1 year	34	36	36	39	44	38	44	46
	Kendra	<1 year	32	37	46	36	44	40	35	38
	Jaeda	<1 year	52	33	57	44	55	44	55	49
	Kate	<1 year	36	36	51	42	50	40	52	50
	Peter	<1 year	52	33	51	32	38	34	48	36
	Vanessa	<1 year	49	29	50	32	58	40	61	42
	Lauren	<1 year	40	34	52	38	51	32	49	34
	Sam	<1 year	40	29	49	37	38	36	35	15

The science activities we did in these workshops were fantastic. We actually feel like we can do some science now! (Lauren, interview, period 3)

All pre-service participants except for Kendra and Peter had increased STOE scores immediately after the workshop (period 2, see Table 3). Kendra described having many resources, but still did not feel she had the content knowledge she believed science teaching requires. Her comments reinforce the importance of hands-on activities in PD (emphasis added):

[Activity books] are helpful, but not as important as knowing the reasons why things work ... **I learn the science content by actually doing it** ... I didn't really walk away from our science lessons [at uni] feeling like I learnt science. (Kendra, interview, period 3)

All pre-service participants had decreased STOE scores once they graduated and began teaching (period 4).

Overall, the workshops increased science teaching self-efficacy beliefs for all but three participants for at least 11 months after the workshops were completed. Hands-on activities were one of the factors consistently identified by both pre-service and in-service participants as contributing to this increase. Discussions with colleagues and the simple explanations used in the workshop materials were also listed as key positive elements of the workshop.

Research question 2: Do short PD workshops produced by science centres affect pre-service teachers differently from in-service teachers?

NSW in-service participants consistently had the highest mean PSTE scores, but also the smallest overall increase (approximately four points) (Figure 2). The pre-service cohort's PSTE scores increased nearly six points, while the ACT in-service cohort increased by nine. For each cohort, the greatest PSTE increase was at period two.

Linear mixed effects model analysis of PSTE differences revealed a significant period effect ($p < .005$). The PSTE scores in periods 2, 3 and 4 were significantly higher than period 1 scores for all cohorts. STOE scores varied little throughout the study. Overall, the pre-service cohort had the highest STOE score, and the in-service cohorts had nearly identical means throughout. Linear mixed effects model analysis of STOE scores revealed an increasing trend over the four periods for the pre-service cohort but not for either of the in-service cohorts.

The interviews revealed some of the factors influencing cohort self-efficacy changes. Elizabeth (ACT in-service) initially described science as her teaching area of least confidence, estimating she taught it less than one hour per week. At interview 2 she reported teaching more than one hour of science per week, attributing this to her working environment:

I'm a lot better than I was confidence wise ... Inspired by my colleagues I think! (Elizabeth, interview, period 4)

The smaller change in the scores of the NSW in-service cohort could also be attributed to the work environment. Simone noticed a difference once she changed schools:

Figure 2. Comparison of mean PSTE and STOE scores for each cohort at each sample period

The kids are highly motivated here [at the new school] ... you have a completely different clientele ... You have very professional parents and you have a much higher interest level and I think this rubs off on to the students, more so than where I was teaching before. (Simone, interview, period 4)

Change in school environment also contributed to Anita's increase in self-efficacy. She was one of the most science-averse participants. When asked what would help her to teach science Anita noted:

... less behaviour problems in the room. No more mental health kids who if we did use [science] equipment would break it and try to kill you. What would help me [to teach science] is no more behaviour problems. (Anita, interview, period 3)

Anita moved to the new school at the beginning of the next school year, four months before interview 2, putting her in a new teaching environment which could have contributed to the maintenance of her increased self-efficacy scores:

I'm not at [the old school] anymore. It's all good now! (Anita, interview, period 4)

The results in Figure 2 indicate that pre-service participants gain the most from the workshops compared to in-service teachers. However, the greatest influence on the effectiveness of PD appeared to be the context in which the teachers were operating—whether or not the school, and/or their colleagues, were supportive of science.

Research question 3: How do teachers' beliefs and previous science experiences influence their perception of science, and their science teaching self-efficacy?

The influence of values and beliefs can be traced back to when teachers were students themselves. Paula was the only ACT participant with no sustained change in PSTE score. Her interview responses highlighted where her negative attitude towards science began:

I was really off science when I was in Year 10 because we had to do all of them ... I just struggled with it. I just didn't enjoy it. It wasn't my cup of tea. (Paula, interview, period 3)

This manifested in her teaching approach; she was reluctant to teach science unless it was absolutely required. Paula acknowledged this, saying science is 'just one of those things that gets missed'. During her next interview, Paula revealed why she could not fit science into the curriculum unless specifically required:

Well ... I'm not confident with getting the things that I need to ... putting my hand on things easily to be able to teach experiments or do stuff in class. And quite honestly a lot of it is just time, it is a time thing .... (Paula, interview, period 4)

Simone (NSW cohort) identified this lack of confidence and prioritisation of science in her colleagues:

I don't think people are confident to teach it at all ... they don't see the science as a big priority which is something that we have to change. We have to change that in the teaching culture, particularly in primary school ... every school I have taught at in the past twenty years is exactly the same .... (Simone, interview, period 4)

Cumulative effects of negative science experiences can be mitigated by personal interest and motivation, or by positive experiences outside the classroom, exemplified here:

I didn't have much of an interest in science in high school. I think that was because of a bad experience with a teacher ... Some of the lecturers at uni weren't that great ... Working [at the science centre] was really good because it was ... not in a school, but it was in education and I got to work with children of all age groups. I even got to do some year 11 physics and that sort of thing and that gave me real confidence. And it was a lot of fun, it made science fun. (Vanessa, pre-service, interview, period 3)

Old values and beliefs were still a strong influence, even among participants whose self-efficacy improved:

... I think I still feel I still have that old teacher sort of style where I think I have to know everything before I can get started. I don't like if children ask me a question and I don't know the answer. Something I think you have to get over a bit ... (Elizabeth, interview, period 4)

Discussion

Science centres are typified by their use of hands-on activities and active visitor engagement (So & Watkins, 2005). The PD workshops used in this study were

developed by a science centre and implemented according to identified best practice in PD delivery. The results show an increase in self-efficacy of all but two pre-service participants immediately after the workshop series, which was maintained for all but three participants for at least 11 months afterwards. Participants consistently identified the hands-on activities using simple, everyday materials as being the most positive and influential part of the workshops, and an important source of their increased confidence. This is consistent with the idea of mastery experiences being a powerful provider of efficacy beliefs (Woolfolk Hoy & Burke Spero, 2005) as also observed by Perera (2010) in his examination of hands-on activities. These results highlight the relevance of science centre programmes to teacher PD.

For pre-service participants, the PD workshops enhanced positive science teaching self-efficacy in ways beyond teacher training alone. Some pre-service participants reported their university lecturers, and the courses themselves, as demotivating and unrealistic, a similar finding to Settlege (2000). Experienced teachers also reported increased science teaching self-efficacy, but their school environment was a major factor in how this increase influenced teaching practice and ultimately the effectiveness of the PD.

The ACT in-service cohort in particular reported collegial support as important in sustaining their increased self-efficacy and motivation inspired by the workshops. In comparison, the NSW in-service participants remained largely unchanged. Those who moved on to new schools expressed greater confidence in their science teaching, simply because they were no longer at their old school. The interviews provide some explanation for the differences in the STEBI scores between the two in-service cohorts, with the ACT cohort reporting an environment more supportive of science teaching and yielding higher STEBI scores. This is supported by Penlington (2008) and Garet et al. (2001) who suggest PD delivered to groups of teachers from the same environment is more effective and will have greater long-term benefit than PD given to disparate groups of teachers, especially if the group is positive and supportive. School environment is a major determinant of if, and how much, self-efficacy increases influence teaching practice, and arguably the effects of any PD.

When interpreting this study's results, the intricacies of the STOE construct may be causing difficulties. Overall, STOE results were less conclusive than those for PSTE. Pre-service teachers were more likely to increase their STOE during the study, but this confidence in their ability decreased at period four once they began teaching full time, probably because of unrealistic expectations based on inexperience (Swars & McMunn Dooley, 2010).

STOE results for both in-service cohorts at first seemed contradictory, with increases in the STOE scale corresponding to decreases in the PSTE scale and vice-versa. But Dellinger et al. (2008, p. 754) proffer the explanation that 'when outcomes are externally controlled or relegated to chance and not due primarily to ability, self-efficacy beliefs provide little information in predicting behaviours'. This is supported in the results of this study, but still might be in part reflecting a weakness in the STOE scale of the STEBI.

The items comprising the PSTE scale, such as the ability to answer student questions, are factors that a teacher can directly control and influence. Teachers are more likely to consistently respond to these items in the STEBI instrument, providing more meaningful results. As Mulholland, Dorman, and Odgers (2004) suggest: if science teaching is evolving, so too should the concept of science teaching efficacy. A modified instrument for outcome expectancy, which reflects this evolution, may be needed. At the least, this highlights the importance of using multiple methods to explore such complex phenomena.

Interview comments from in-service participants confirmed Pajares' (1992) position that long-held beliefs are difficult to change, with some participants acknowledging they needed to re-evaluate these beliefs because they can reduce confidence. One respondent's long-held negativity towards science, due to negative experiences in science throughout her own education and training, meant she avoided teaching it altogether. These resulting strongly held negative beliefs about science overshadowed any potential gains the workshops may have provided. This is consistent with the findings of Tosun (2000) and underlines an important consideration for PD providers and a universal challenge for teacher educators (Angus, Olney, & Ainley, 2007; Angus et al., 2004; Stevens & Wenner, 1996).

One clear option is to address teachers' beliefs as soon as they begin training, and through PD throughout their careers, as has been suggested before (Hanuscin, Akerson, & Phillipson-Mower, 2006; Lumpe et al., 2000; Palmer, 2006b, Pin'ro, 2004). The pre-service participants credit the hands-on activities and simple explanations of these workshops as contributing confidence and understanding they felt they were missing. For some, this changed their belief in their ability to teach science before they began working in schools. The results from this study suggest that PD offered by science centres could be an effective means of addressing teacher beliefs, especially for pre-service teachers.

The total time spent working with the teacher participants in this project was under five hours. Kahle and Boone (2000) argue that a PD intervention this brief would achieve nothing tangible nor long lasting. Supovitz and Turner (2000) assert that effective PD takes at least 80 hours. This study tells a different tale, with self-efficacy maintained or enhanced in all but three participants nearly a year after the workshops. Our results are comparable to those reported in a study on the impacts on confidence and science teaching self-efficacy of a 13 week science methods course at a university (Palmer, 2006a). Although possible that the repeated administration of the survey may have increased awareness of self-efficacy concepts, the explicit description of the surveys and purpose was only given in period 1, almost a year before the final survey period. We argue that the effect would be minimal and the findings here are worthy of further exploration.

Implications for PD Providers

This study indicates that science centres, and arguably other informal science education institutions, can produce effective PD opportunities for teachers. The key

attributes of informal science education PD are enjoyable, accessible and comprehensible content (Melber & Cox-Peterson, 2005; So & Watkins, 2005), developed by institution teachers considered as subject matter experts (Aubusson et al., 2010). They focus on visitor engagement and hands-on activities, which the literature identifies as core components of effective PD (Desimone et al., 2002; Watters & Ginns, 2000). At the very least, PD providers should consider emulating the informal science education style of content development.

The effectiveness of the workshops was influenced by the context of the participants. Those who worked in schools that were not supportive of science, or who experienced barriers to effective teaching through behavioural problems in students or different educational systems, tended to show less positive self-efficacy beliefs. To maximise the effectiveness of any PD offered to teachers, it is important to understand the context in which they operate. Additionally, it is useful to gauge if teachers have any potential barriers they may be bringing with them from their previous experiences with science. This is not to suggest that teachers should submit background information before participating in PD. Rather, wherever possible, PD should be tailored and delivered with an understanding of the context in which the participants operate, and include mechanisms that will support effective uptake and enhancement of the desired outcomes. This could be simply creating a community of PD participants that meets either face to face or online to share problems and ideas, consistent with creating a community of learners espoused in the literature (Garet et al., 2001; Penlington, 2008; Watson et al., 2007) which should create a more positive environment for reform efforts (Judson & Lawson, 2007).

Limitations

The primary limitation of this study was the small sample size, but recruiting teachers into research is notoriously difficult (see for example Watters & Ginns, 2000; Woolfolk Hoy & Burke Spero, 2005). So too is avoiding untenable attrition rates in longitudinal studies. It is therefore noteworthy that out of the 21 participants who initially signed up, 20 stayed throughout. One was excluded from the final results as she was not teaching.

Recommendations for Further Research

Self-efficacy is useful for predicting teacher behaviour; however, the results obtained in this study, and others, indicate possible weaknesses within the STOE scale of the STEBI instruments. This has not been fully explored in this article, and further research is required. Measuring expectations is a complex task, and as teacher training and student populations change, it stands to reason that expectations will also change. Therefore the STOE scale needs to be revisited to ensure that it measures outcome expectancy in a manner appropriate to prevailing educational practice and training, to allow the STEBI to continue to be used as an effective instrument in science education research.

Conclusions

Teachers need positive learning experiences in science, and an environment that supports science teaching, in order to want to engage in science. Informal science education institutions can, and do, play a part in providing these experiences to the wider public, but their impact in teacher PD and teacher training is largely uncharted. The results of this study show that even a few short science centre developed PD workshops, incorporating hands-on activities and simple explanations, are capable of enacting a long-term positive influence on the science teaching self-efficacy beliefs of pre-service and in-service teachers. The environmental context of teachers is one of the main factors limiting the success of PD. Further studies are required to look at how places like science centres and museums can work with teacher educators, particularly in universities, to assist in the training of new teachers in science.

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